METAL WORK

FOR

TECHNICAL & HIGH SCHOOL STUDENTS

• BOOK 3 •

WITH USEFUL TABLES & DATA

BY

A. L. HUGHES

Late Head Teacher of Metal Work,
Central Technical School, Newcastle.

DYMOCK'S BOOK ARCADE LTD.
SYDNEY

First Edition - - 1945
Reprinted 1947, 1951, 1955, 1957, 1959, 1961

Registered at the G.P.O., Sydney, for
transmission by post as a book.

Wholly set up and
printed in Australia
by Simmons Limited,
32 Parramatta Rd.,
Glebe, Sydney.

FOREWORD

Teachers and students alike have long felt the need of a suitable elementary text book on Metal Work.

The author has supplied this need. He is a craftsman who has had considerable experience as a teacher of Junior Technical and High School Classes.

The book is well-arranged and the matter has been presented on good lines.

Tools, processes and materials are dealt with in the different chapters in a thorough manner. Useful summaries, questions and tests have been provided.

The book is specially recommended to those who are themselves preparing, or preparing others, for the standard examinations in metal work.

JOHN R. GARDINER,
Senior Technical Supervisor.

Department of Education,
Sydney, N.S.W.

PREFACE.

The object of this present work is to provide both student and teacher with a manual covering elementary Metalwork and Workshop Practice in such a way as to bring a source of such information within easy reach of the average student. An endeavour has been made to set the work out progressively, and in a manner as simple as possible, without delving into the subject of mechanical engineering beyond the point required by general knowledge and usefulness, so that, in this way, the student may have a handbook designed to meet his requirements through the early part of his training or apprenticeship course.

Workshop methods to-day lean more and more towards specialization as a result of mass production, consequently the young student of engineering tends to fall into a groove, confining him to one or at least a very few operations; this is detrimental to him, not only as an engineer but also as an individual. It therefore behoves every apprentice, whose ambitions soar beyond his daily grind, to take advantage of every facility offered him in the way of technical books and institutions to increase his general knowledge and broaden his outlook. Foremen in engineering establishments, as well as teachers of the subject, would do well to remember that on their shoulders rests a greater responsibility than that of merely imparting knowledge; on them, to a large degree, depends the future of the apprentice or students under their care. If they are careful to see, in the case of teachers, that, the instruction given, or the curriculum drawn up, covers a wide field, and, in the case of foremen, that the work of their

apprentices be varied to include all branches of their trade, they will have performed a service, not only to the young artisan, but also to the community as a whole.

This publication should be of value to those who are interested in Metalwork as a means of utilizing some of their leisure hours. It would give them a general knowledge of the tools, equipment and processes necessary to pursue such an interest. Indeed, few subjects lend themselves more readily than metalwork to hobbywork, for many of the tools required can be improvised and the equipment necessary is little and inexpensive, nevertheless the range of work is wide and varied with its possibilities unlimited.

On the hobbyist as well as the student must be impressed the fact that Metalwork, as a branch of Engineering, is an exact science, and particularly in the early stages, it is necessary to persevere until the required degree of accuracy is obtained. Later on the keen craftsman will find that, as a result of his early training, it is impossible to do a job any way but the right way, remembering always, that "near enough is not good enough."

At the end of most subjects dealt with, a summary has been added, which will do service as a blackboard summary for the teacher or as a useful method whereby the student may enter the lesson into a class notebook. The form taken where possible, is that of setting out the subject clearly step by step. Also at the end of each subject is a group of questions which may be useful for instructional purposes, and, included at the end of the book, is a series of short questions, arranged progressively in accordance with the subject matter, which will serve to test periodically and quickly what knowledge has been gained by the student.

I desire to express my thanks for, and sincere appreciation of, the help given me by the following: Mr. John R. Gardiner, Senior Technical Supervisor, Dept. of Education, N.S.W., for writing the Foreword and offering

many helpful suggestions; my brother, Mr. T. S. Hughes, A.S.T.C., A.M.I.E.A., Mr. B. Platt, M.Sc., Mr. C. Leigh Cook, M.A., Mr. F. Pearce, and certain members of the staff of the Commonwealth Steel Company Ltd. for their help with information, drawings, corrections and suggestions; to McPhersons Pty Ltd., Sydney and Melbourne, Wm. Adams & Co. Ltd., Sydney, Goodall & Co. Ltd., Sydney, and Scruttons Pty Ltd., Sydney, for the loan of blocks used in this publication; and to the Superintendent of Technical Education, N.S.W., and the Board of Secondary School Studies, for their permission to print extracts from standard technical examination papers which form the basis of the series of examination questions included in the appendix of this work.

A. L. HUGHES.

Newcastle

CONTENTS

TITLE	PAGE
ALLOYS ... ... Principal Alloy Groups. Composition, Properties, Characteristics and Uses of Alloys.	159
ALLOY STEELS ... ... Manufacture and Uses of. Alloying elements, Characteristics and Properties. Cutting Steels and Alloys. Special Steels, groups and uses.	150
ART METAL WORK ... ... Metals commonly used for Art Metal work. "Raising" an Ash Tray. Steps in the procedure.	333
BELTS, PULLEYS AND POWER TRANSMISSION ... Definition and Classification. Care and methods of using belts. Pulleys, shafting, couplings, bearings, etc. Power Transmission—Belt and Gear drives. Data and formulae for calculating horse-power, diameters and speeds.	268
BOLTS, NUTS AND SCREWS ... ... Methods of Fastening and Binding. Principal Types and Uses. Nut Locking Devices. Keys and Keyways.	189
BRAZING ... ... Comparison of Brazing and Soldering. Spelters, Flux, Heat. Method of Brazing. Silver Soldering. Aluminium—soldering and protection of.	27
CALIPERS... ... ... Main Types and Uses. Using the Calipers. Setting the Calipers.	122
CHISELS ... ... Common Types and Uses. Cutting Angles—Variation for different metals. Using the Chisels.	74
CONSTRUCTION... ... ... Steps of Procedure. Method of making—(a) A pair of Calipers. (b) A small Scoop.	327
DEVELOPMENTS ... ... Definition of development. Development of the common Geometrical figures.	341
DIVIDERS ... ... Main types and uses. Using the Dividers. The Trammels.	118
DRILLS AND DRILLING ... ... Principal Types and Uses. Reamers and their uses. Drilling Machines. Points to observe when drilling, Lubricants.	177
FERROUS METALS ... ... Common Forms, Properties, Characteristics and Uses. Furnaces and Processes of Manufacture.	136
FINISHING AND POLISHING ... ... Treatment of various Metals, *e.g.* (a) Iron and Steel. (b) Copper and Brass.	338
FILES AND FILING ... ... Distinguishing Characteristics of Files. Types and Uses. Using the Files—Methods of Holding, etc.	79

CONTENTS (Continued)

TITLE PAGE

FITS AND TOLERANCES 220
Definition of Fits. Classification of British and American standards. Definition of Tolerance, allowance and limit. Degrees of allowance. Methods of indicating tolerance.

FLUXES 20
Cleansing and Protective Fluxes. Types and Uses of each. Preparation of Zinc Chloride.

FORGEWORK 286
Forge, Fire and Fuels. Forgework Tools, Operations—Primary and Secondary, Classes of Welds. Heats and Fluxes.

GRINDING AND SHARPENING 320
Grindstones—Use, Care, and Speed. Grinding Wheels—Speed, Grades and Care. Oilstones—Use and Care.

HACKSAWS 93
Types, Parts and Uses. Using the Hacksaw. Method of Holding. The Piercing Saw.

HAMMERS 69
Common Types of Hand Hammers. Fitting the Handle. Using the Hammer, Sledge Hammers and their Uses. Grading of Hammers.

HEAT TREATMENT OF METALS 165
Methods of Treatment. Annealing, Hardening, Cooling media. Tempering, Case-hardening, "Nitriding." Temperatures and Tempering colours. Heating by Induction.

LATHES AND LATHE WORK 227
Construction, Parts, Uses and Accessories. Lathe Tools, Types and tipping of. Lathe Work—principal operations. Lubrication—Cutting compounds, etc.

MALLETS 45
Principal Types and Uses. The Tinman's Dresser and its Uses.

MARKING-OFF, MEASURING AND TESTING TOOLS 101
Definition—"Marking-Off" Preparation of Copper-Sulphate solution. Principal Marking-off, Measuring and Testing tools and their uses.

MOULDING AND CASTING 303
History. Application. Metals used. Reduction of Metals—cupola and crucibles. Divisions of Moulding. Tools used. Core-making. Patterns. Ramming, Venting, Pouring, etc.

NON-FERROUS METALS 155
Principal Non-Ferrous Metals in common use. Properties, Characteristics and Uses.

PLIERS 67
Principal Types and Uses. Care of the Pliers.

PROPERTIES OF METALS 128
The chief Properties and Characteristics of Metals.

SEAMS, JOINTS AND EDGES 51
The Use of Seams and Joints. The Common Forms. Soldered, Riveted and Brazed seams and joints. Methods of finishing Edges.

SCRAPERS 89
Definition of Scraping. Types in common use. Holding and Using the Scraper. Method of Sharpening.

CONTENTS (Continued)

TITLE	PAGE
SHAPING MACHINES	247
Classification, types, parts and uses. Methods of Drive, Feed, Cutting and Holding work. Shaper Tools, Accessories and Exercises. Calculation of Cutting Speed, etc.	
SHEET METALS...	40
Principal Groups—Ferrous, Covered, Pure and Alloyed metals. Chief metals in each group. Gauging Sheet Metals.	
SNIPS, TINMAN'S	11
Types, Parts and Uses. Care of the Snips. Points in Using the Snips. The Bench Shears.	
SOLDERING BIT	15
Types, Parts and Uses. The value of Copper for the "head" of the bit. Heating and care of the Copper Soldering Bit.	
SOLDERING	23
Definition of Soft Soldering. Uses of the Process. Soft Solders—Composition, Melting Point and Uses. Process of Soldering.	
SPANNERS	215
Common Forms and Uses. Using the Spanners—Points to observe.	
STAKES	48
Principal Types, Parts and Uses. The use of the Mallet in conjunction with the Stakes. The Folding Bars, and their uses.	
STOCKS AND DIES	211
Method of Cutting External Threads. Types of Stocks and Dies. Using the Stock and Die. Lubrication. The Screw Plate—Uses, etc.	
SQUARE, ENGINEER'S	112
Common types and their uses. The Try-square—Three methods of manufacture. Method of Testing the Square.	
TAPS AND TAPPING	205
Screw-cutting. Taps for cutting Internal Threads. Taps in a "Tap Set." Method of Tapping—Depth of holes. Methods of Calculating and Table of Tapping Sizes. Lubrication.	
THREADS, STANDARD SCREW	199
Chief requirements in a Screw Thread. Division of Threads into Groups. Principal Types of Threads, Details and Uses.	
TINNING THE SOLDERING BIT	18
Reason for "Tinning" a Bit. Steps in the procedure. Care of the "Bit" after Tinning.	
TINPLATE AND GALVANISED IRON	172
Uses of T[illegible]. [illegible] the term "Galvan[illegible] Terne plate. [illegible]	
VICE, ENGINEER'S	59
Types of Vices—The Leg and Parallel types—"Instantaneous" Grip Device—Uses. Height of the Vice. The Hand Vice, Types and Uses. Vice Clamps and Filing Board.	
WELDING	32
Classification—Autogenous and Heterogeneous. Methods of Welding, *e.g.* Oxy-acetylene, Thermit and Electric.	

APPENDIX

EXAMINATION PAPERS	362
TABLES	379
TESTS	351

THE TINMAN'S SNIPS.

It might be said that the snips are the most important of all the sheet metal worker's tools. Like the majority of engineers' cutting tools, snips have the cutting portion, or the blades, made of tool or cast steel, hardened or tempered to a sufficient degree to cut other metals.

The handles of snips are made of mild steel, this metal being welded to the tool steel of the blades. The main reason for the use of this softer and more ductile metal for the handles is that, if the snips are subjected to a greater strain than they are made to withstand, the handles will "give," i.e., they will bend slightly, rather than break, as they would tend to do if made of tool steel.

The rivet (pivot) is also made of mild steel so that it may be burred over more readily when forming the head which will hold the two parts together.

The cutting action of the snips is known as a shearing action, i.e., the two blades slide over each other with a consequent severing of the metal in between.

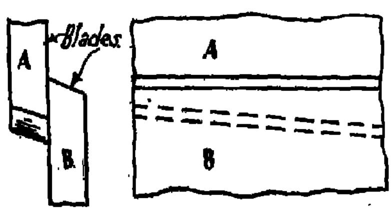


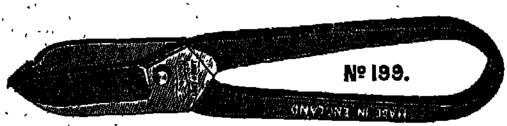
DIAGRAM OF SHEARING ACTION.

The snips are used for cutting sheet metal not exceeding $\frac{1}{16}$ inch in thickness. Thicker metals should be cut with

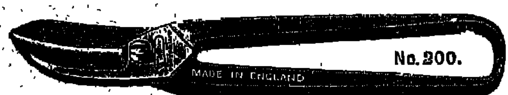
scotch shears, bench shears or cold chisels. Snips should not be used for cutting wire, as this causes pressure to be applied over a very small area of the blades, which tends to gap them.

There are many types of snips in common use, the two main types, however, being the "Straight" Snips and the "Curved" or "Bent" Snips. These may be obtained in lengths varying from eight to fourteen inches. Another type called "Scotch Shears" as shown is designed for work of a heavier nature, *e.g.*, cutting thicknesses

TYPES OF SNIPS.



Straight.

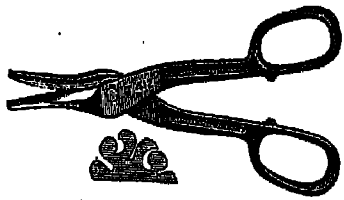


Curved.

Scotch Shears.

slightly exceeding those cut with the ordinary snips.

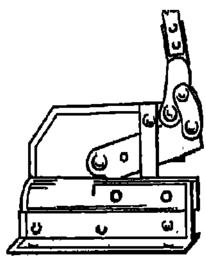
The Straight Snips are used for cutting along straight lines and around the outside of curves (convex cutting).



UNIVERSAL SNIPS.

The Bent Snips are used for cutting out holes in sheet metals and around the inside of curves (concave cutting).

The Universal or Circular Cutting Snips will cut curves, circles or straight lines. It is possible when cutting with this type to turn right or left or to double back again without kinking the metal.



BENCH SHEARS.

The Bench Shears, as shown, are firmly secured to the bench and provide a very convenient and satisfactory means of cutting sheet metals up to, but not exceeding $\frac{3}{16}$ inch in thickness.

Points in Using the Snips:

1. The snips are held in the right hand with the index finger between the handles. The finger in this position has the effect of a spring and forces the handles apart. Light types of snips can be obtained with a spring device for this purpose, fitted between the handles.

2. The snips should be held at about the forearm's length from the body and more or less stationary. By this it is meant that the work should be moved in towards the mouth of the snips, rather than have the snips move into or "chase" the work.

3. The work should be cut well up in the mouth of the snips. It is not advisable to allow the blades to close completely at every cut, as this leaves small ridges on the work, consequently marring the smoothness of the surface.

4. For small work it is often convenient to clamp the lower handle of the snips in a vice and to effect the cut by using the top lever only.

5. To ensure clean and smooth cutting, the snips should be kept keenly sharpened with the cutting edges at an angle of 87°.

SUMMARY.

Classification : Cutting or shearing tools.

Types : There are two principal types of snips :—
(a) Straight snips.
(b) Curved or bent snips.

Parts : Handles, blades, rivet and cutting edges.

The handles and rivet are made of mild steel and the blades of tool (shear) steel, welded to the handles. The angle of the cutting edges is 87°.

Uses : The Straight snips are used for cutting along straight lines and the outsides of curves (convex cutting).

The Bent snips are used for cutting around the inside of curves (concave cutting).

Snips are used by plumbers and all sheet metal workers. They should never be used for cutting metals exceeding $\frac{1}{16}$-inch in thickness.

Questions :

1. Name the two common types of snips.
2. State the uses of both types.
3. Name the parts of the snips.
4. Name the materials used for the various parts.
5. What is the angle of the cutting edges ?

THE SOLDERING BIT.

The most common method of applying soft solders is with a heated copper or soldering bit, often misnamed a soldering iron. Copper has been found to be the most suitable metal for this tool for three main reasons :—

1. It is a good conductor of heat and so gets hot quickly.
2. It retains heat.
3. It has an affinity for solder ; it readily collects and holds this alloy.

The soldering bit consists of three main parts :—

(a) A small block of copper, usually square in section, which is forged so that it tapers to a point at one end. This is called the " bit " or " head."

(b) A mild steel rod or stem which is screwed or riveted into the head, at one end, and is pointed, or tang-like, at the other, for entering the handle.

(c) A wooden handle, preferably beech or hickory, fitted with a ferrule to prevent it splitting when forced on to the stem. The ferrule is usually made of tinplate or brass.

SOLDERING BIT.

Soldering bits are specified by the weight of the head and can be obtained in varying shapes and sizes, according to the requirements of the work. The most common is the square-pointed bit, with weights varying, in common practice, from ½lb. up to 1½lbs. Another common type is the " hatchet " bit, which, for certain purposes, is often found to be handier than the straight bit ; for example, when soldering on the inside of narrow objects.

The copper bit should only be used for soldering thin metals, because the two pieces of metal to be joined together must be brought to the same temperature, by the bit, as that necessary for fusing the solder; it carries insufficient heat for thick metals.

PRIMUS AND HATCHET BIT.

Care should be taken, when heating, to ensure that the body of the bit, as well as the point, is heated. By so doing the bit will keep hot much longer. It is better not to bring the point into direct contact with the flame, as this tends to "burn" it, gradually causing it to become rough and mis-shapen.

Heating: There are many ways of heating copper bits, the most common being by gas, electricity, kerosene or coke stoves and forge. Most of these methods are satisfactory, although gas is probably the best, as the temperature can be more readily and satisfactorily controlled.

SUMMARY.

Classification: Joining and fixing tool.

Types: There are two principal types of soldering bits :—

(a) The Square-headed bit.
(b) The Hatchet bit.

Parts: Head, stem, handle (and ferrule).

The head is made of copper and is attached to the stem, which is made of mild steel. The stem has a tang-like end for entering the handle. The handle is made of wood, usually beech or hickory, and is fitted with a ferrule to prevent splitting.

Uses: The soldering bit is used by plumbers and sheet metal workers for soft soldering sheet metals.

The soldering bit is specified by the weight of the head, *e.g.*, $\frac{3}{4}$lb. and $1\frac{1}{4}$lb. head.

Questions:

1. Name two types of soldering bits.
2. Name the parts of a bit.
3. Write down the materials used in the various parts.
4. Why is copper preferred to other metals for the head of the soldering bit?
5. How are soldering bits specified?

TINNING THE SOLDERING BIT.

Before a new soldering bit can be used, it must be "tinned," that is, the point of the tapered part must be coated with solder, otherwise the solder for making the joint will not adhere to it.

To tin the bit it should first be heated to a dull red, then clamped in a vice and the tapered faces filed until clean metallic surfaces appear. The point is next dipped quickly into the flux (Zinc Chloride) to further clean the surfaces and to enable the solder to flow more freely over them. The faces are now rubbed on a piece of solder, giving them a thin coating of the metal and a bright, silvery appearance. If treated with reasonable care, and not overheated or "burnt," a copper bit should remain fit for use for a long time.

There are two important reasons why it should not be overheated, one having an immediate, and the other a remote, effect:—

(a) *Immediate effect*: Overheating causes the "tinning" to melt off the bit, thereby rendering it useless, for soldering purposes, until it has been retinned.

(b) *Remote effect*: Continued overheating will cause the head to deteriorate gradually and lose its shape, which means that, with repeated filing to restore the shape, the bit will obviously not last as long as one treated with greater care.

Note: It will be noticed that the words "tinned" and "burnt" are shown above in inverted commas, to signify that they are trade terms. The copper bit is not coated with tin, but with solder, which, being much like tin in appearance, gives rise to the word "tinned," nor does the copper bit actually burn, as for example, we could burn a piece of wood, but has been subjected to unnecessary overheating, which causes a gradual deterioration of the metal.

SUMMARY.

Before a new soldering bit can be used, the joint must be "tinned," otherwise the solder, for making the joint, will not adhere to it.

The method of tinning a bit is as follows :—

Step 1 : Heat the bit to a dull red.

Step 2 : Clamp in a vice and file the faces until clean metallic surfaces appear.

Step 3 : Dip in the flux (Zinc Chloride).

Step 4 : Rub on solder to coat the faces.

The bit is now "tinned" and ready for use. Care should be exercised to prevent it being overheated or burnt, thus shortening its term of usefulness.

Questions :

1. Why is it necessary to tin a soldering bit ?
2. Write down the steps in the procedure.
3. Why must a bit not be overheated or "burnt" ?
4. Why are "tinned" and "burnt" trade terms ?
5. Which flux is used in the process of "tinning a bit" ?

TINNING THE SOLDERING BIT.

Before a new soldering bit can be used, it must be "tinned," that is, the point of the tapered part must be coated with solder, otherwise the solder for making the joint will not adhere to it.

To tin the bit it should first be heated to a dull red, then clamped in a vice and the tapered faces filed until clean metallic surfaces appear. The point is next dipped quickly into the flux (Zinc Chloride) to further clean the surfaces and to enable the solder to flow more freely over them. The faces are now rubbed on a piece of solder, giving them a thin coating of the metal and a bright, silvery appearance. If treated with reasonable care, and not overheated or "burnt," a copper bit should remain fit for use for a long time.

There are two important reasons why it should not be overheated, one having an immediate, and the other a remote, effect :—

(a) *Immediate effect* : Overheating causes the "tinning" to melt off the bit, thereby rendering it useless, for soldering purposes, until it has been retinned.

(b) *Remote effect* : Continued overheating will cause the head to deteriorate gradually and lose its shape, which means that, with repeated filing to restore the shape, the bit will obviously not last as long as one treated with greater care.

Note : It will be noticed that the words "tinned" and "burnt" are shown above in inverted commas, to signify that they are trade terms. The copper bit is not coated with tin, but with solder, which, being much like tin in appearance, gives rise to the word "tinned," nor does the copper bit actually burn, as for example, we could burn a piece of wood, but has been subjected to unnecessary overheating, which causes a gradual deterioration of the metal.

SUMMARY.

Before a new soldering bit can be used, the joint must be "tinned," otherwise the solder, for making the joint, will not adhere to it.

The method of tinning a bit is as follows :—

Step 1 : Heat the bit to a dull red.

Step 2 : Clamp in a vice and file the faces until clean metallic surfaces appear.

Step 3 : Dip in the flux (Zinc Chloride).

Step 4 : Rub on solder to coat the faces.

The bit is now "tinned" and ready for use. Care should be exercised to prevent it being overheated or burnt, thus shortening its term of usefulness.

Questions :

1. Why is it necessary to tin a soldering bit ?
2. Write down the steps in the procedure.
3. Why must a bit not be overheated or "burnt" ?
4. Why are "tinned" and "burnt" trade terms ?
5. Which flux is used in the process of "tinning a bit" ?

FLUXES.

Fluxes are many and varied and differ according to the nature of the metal to be soldered. They may be conveniently divided into two main classes :—

1. *Those which have a cleansing action*, removing any oxide coating from the metal: Sal-Ammoniac, hydrochloric acid (spirits of salt) and chloride of zinc are fluxes of this type.

2. *Those which have a purely protective action*, preventing oxides forming on previously cleaned metal surfaces: tallow, olive oil and resin are examples of this type.

The choice of a flux depends, to a large extent, upon the fusibility of the metal to be soldered and the readiness with which it oxidises. Thus, tin (or tinplate), which does not easily oxidise and which fuses readily, needs a fusible solder and a flux which may be merely protective and which need have no cleansing action. Such a flux is resin, although zinc chloride is generally used on account of its greater mobility and convenience. On the other hand, zinc is a more difficult metal to solder than tinplate, as it quickly oxidises and therefore needs a cleansing flux. In this case hydrochloric acid is used, with the result that the zinc oxide is dissolved and a clean surface presented to the solder.

The most common flux is zinc chloride ($Zn\ Cl_2$). This is prepared by dissolving zinc (preferably granulated) to excess in muriatic acid (spirits of salt) until it ceases to effervesce, or give off gas. When this happens the acid is said to be saturated or "killed," hence the name "killed spirits of salt."

For general soldering purposes, zinc chloride can be broken down with an equal volume of water, and still be sufficiently strong, thus considerably reducing the cost of manufacture.

If required in paste form, the zinc chloride solution can be evaporated by boiling. The resultant crystals are ground and then mixed with an equal quantity of petroleum jelly. It is less likely to cause rust if used in this form.

FLUX	METAL	REMARKS
Zinc Chloride (Killed Spirits of Salt)	Tinplate, Iron, Copper, Brass	Has a cleansing action. Induces corrosion if not washed off the joint after soldering.
Hydrochloric Acid (Dilute) (Spirits of Salt)	Zinc Galvanised Iron	A cleansing flux. Unites with the zinc to form zinc chloride.
Sal Ammoniac (Ammonium Chloride)	Iron Copper	Has a cleansing action. Used for the "tinning" of copper.
Resin	All Metals	Has a protective action. Is used generally for electrical work.
Tallow	Lead	Protective fluxes. Suitable for most metals with a low melting point.
Gallipoli Oil (Green Olive Oil)	Pewter White Metal	

N.B.: Resin is the flux generally used when soldering electrical apparatus.

SUMMARY.

Fluxes are used when soldering in order to:-

1. Clean the metals to be soldered.
2. Assist the solder to flow freely.
3. Prevent the formation of oxides and to dissolve existing oxides.
4. Promote the fusion of the metals, the "fusion" point being that at which a metal changes from a solid to a liquid state upon the application of heat.

Fluxes are many and varied, the most common being zinc chloride ($Zn\ Cl_2$), or killed spirits, which is prepared by dissolving zinc in muriatic acid until gas ceases to be given off. For general soldering purposes a solution consisting of equal volumes of killed spirits and water will be sufficiently strong.

Questions :

1. State three reasons for using a flux.
2. How would you prepare killed spirits ?
3. State a flux you could use when soldering :
   (a) Tinplate.
   (b) Galvanised Iron.
   (c) Copper.
   (d) Pewter.
4. What flux is used when soldering electrical work ?
5. What liquid would you use to " break down " zinc chloride ?

SOFT SOLDERING.

Soft soldering is the process of joining two metals by a third metal, more fusible than either, but capable of forming an alloy with each. The metals commonly joined by this method are the "tinned" metals, *e.g.*, tinplate and galvanised iron, and the more fusible metals, such as zinc, lead, tin and pewter. It is also largely used for brass and copper, but only where a strong joint is not essential and the low melting point of the solder not detrimental.

The following table shows the soft solders in common use :—

NAME	COMPOSITION			Melting Point (Approx.)	REMARKS
	Lead	Tin	Bismuth		
Plumber's Metal ...	2	1	-	460° F.	Strong — is used for general plumbing work.
Tinman's Solder (Ordinary)	1	1	-	425° F.	Used generally for sheet metal work.
Tinman's Solder (Fine) ...	1	2	-	365° F.	Flows freely—is used for high-class sheet metal work.
Pewterer's Solder ...	1	1	1	240° F.	Very fusible — is used for joining metals with a low melting point.

Lead melts at 620° F.
Tin melts at 475° F.
Bismuth melts at 487° F.

Soft Solders :

Soft solders, according to their composition, are fusible at temperatures varying roughly between 200° F. and 500° F. Whilst suitable for nearly all metals, they are most commonly used for joining "tinned" metals and on articles which will not afterwards be subjected to any great heat. They are composed mainly of tin and lead, in varying proportions, with the addition of bismuth in the case of pewterer's solder, to lower the melting point below that of pewter.

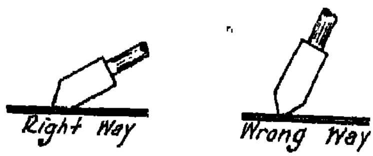
It will be seen, by reference to the table on p. 23, that, when tin and lead are melted together, the melting of the resultant alloy varies considerably from that of its constituent metals. This is particularly noticeable in the case of pewterer's solder, where the addition of bismuth to the lead and tin brings the melting point of the solder very much lower than the lowest of the constituent metals.

Process of Soldering : If the following points are noted, prior to commencing operations, they will help considerably in the production of better work :—

1. The metals to be joined must be perfectly clean.
2. Wherever possible, keep all seams or joints in line.
3. Make sure that the soldering bit is clean and well tinned.
4. Use as little solder as possible.
5. Get the solder into the joint and not on to the metal round about it.

The pieces of metal to be joined must be cleaned at the edges and held in position, either with the hand or by some other means convenient to the worker. Flux is applied with a small brush. The next step is to see that the copper bit is sufficiently heated. This can be judged by holding it about six inches from the face, when, if hot enough, the heat will be perceptible. The bit is now dipped quickly into killed spirits, to clean the point by removing any oxides, and then rubbed on a

piece of solder, care being taken that only a small amount is picked up. This is then applied to the work. The bit must be moved slowly along the joint, giving the heat time to penetrate the metal, being sure not to apply it with a backward and forward motion, as this nearly always results in a rough joint.



USING THE SOLDERING BIT

The soundness of a joint can generally be judged by its appearance, which should be smooth and bright. If the solder does not flow freely or lies in lumps on the work, it proves that the bit was not hot enough, but if rough or sandlike in appearance, the bit was either too hot or applied too quickly.

When soldering metals, other than those which have tinned surfaces, the edges should be separately tinned, i.e., coated with solder, before uniting. This is almost similar to the process of "sweating," which is the application of a thin coat of solder to the faces of two pieces of metal and then heating them until they unite. Sweating is often necessary when the job is either too small, or too large, for the application of a soldering bit to be effective.

SUMMARY.

In the process of soft soldering, we aim to unite various metals by a metallic substance in a state of fusion, which substance will harden when cold and so render a joint solid. A good solder will flow freely and firmly unite with the metals being soldered. Also its melting point must be below that of these metals. Soft solders are

fusible at temperatures varying roughly between 200° F. and 500° F. and are suitable for soldering nearly all metals.

Solders are composed of tin and lead, with the addition of bismuth, when a low melting point is required. They should be applied with a clean, well-tinned, copper bit drawn very slowly along the joint, using as little solder as possible, and making sure that what is used is placed well into the joint, and not on to the metal round about it.

Sweating is a process similar to soldering, the surfaces of the metals to be joined are coated with solder and then sufficient heat applied to unite them.

Questions:

1. What do we aim to do in the process of soft soldering?
2. Why must the melting point of solder be lower than that of the metals to be soldered?
3. What is meant by "sweating"?
4. Write down the composition and melting point of tinman's solder (fine).
5. Why must soldered articles not be subjected to a great heat?

BRAZING.

Hard Soldering, or **Brazing,** as it is more commonly called, is a method of joining metals, such as brass, copper and steel, with a fusible alloy. It is somewhat similar, in principle, to the soft soldering process, but differs mainly in the fact that the uniting alloy will only fuse at, or above, red heat, thus making it impossible for them to be applied with a copper bit. Brazed joints are also much stronger than soldered joints and offer far greater resistance to heat.

Spelters : The alloys used for uniting metals when brazing are termed " spelters," and are usually copper-zinc, i.e., brass alloys, rich in zinc. The following table shows the approximate proportions of copper and zinc in the spelters used for brazing certain metals :—

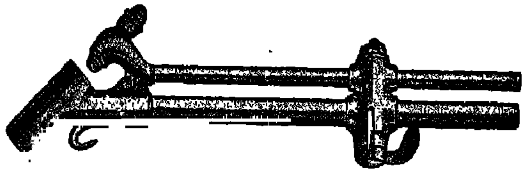
METAL TO BE BRAZED	COMPOSITION OF ALLOY	
	COPPER	ZINC
Brass	50 per cent.	50 per cent.
Copper	60 „ „	40 „ „
Iron and Steel	70 „ „	30 „ „

Spelters can be obtained in wire, stick or granulated form and must, of course, be chosen with a melting point which falls below that of the metals to be brazed.

Flux : Borax is used as a flux when brazing all metals. Its value in this respect is due to :—

1. Its ability to dissolve metallic oxides.
2. It quickly fuses into a glass-like paste over the surface of the work, thus preventing the formation of further oxides.

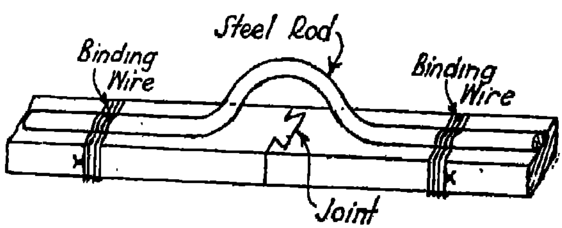
3. It facilitates the flowing of the spelter.



BLOW PIPE.

Heat: For purposes of brazing the heat is usually supplied by a gas blowpipe and foot-bellows, or a blow-lamp, the former being the most satisfactory method. It is advisable to use these sources of heat in conjunction with a small hearth, filled with coke, which concentrates the heat about the joint and so facilitates the process.

Method of Brazing: The pieces to be brazed should be fitted together in some convenient form and firmly secured by clamps or binding wire. Sufficient spelter and borax are mixed together with a little water to form a thin paste which is spread along the joint. When this has been done, the work is placed on the hearth, or held with pliers or tongs, and the heat applied.



METHOD OF SECURING JOINT WHEN BRAZING.

The application of heat should be gentle at first to evaporate the moisture; at this stage the borax bubbles up into a froth. The heat is then increased until the joint is a dull red colour, at which temperature the borax will fuse like glass. Upon increasing the heat to a bright

red colour a small blue flame will be noticed, indicating the fusion of the spelter. A gentle tapping of the work, at this stage, will assist the spelter to flow evenly into and through the joint. Often, however, the spelter will "flush," that is, become absorbed in the joint of its own accord.

The process is now complete, and after the joint has been flushed off the work should be withdrawn from the heat and allowed to cool. If necessary the joint should be filed to remove any surplus metal and to improve the appearance.

JEWELLER'S BLOW PIPE.

Silver Soldering : This is a process used largely by jewellers for joining metals. It is identical, in principle, to that of brazing, except that in small work a blowpipe is used and the uniting alloys have a low melting point. On work of a larger nature the heat is usually supplied by means of an air-acetylene blow-pipe or an atmospheric gas blowpipe and, as with brazing, powdered borax is used as a flux, a paste being made by mixing the borax with water.

To achieve successful silver soldering it is necessary to ensure that the parts to be joined are kept in close, firm contact throughout the operation, thus aiding the ready flow of the uniting alloy, which results in a neat, clean and very strong joint.

The work should be heated slowly at first. This has the effect of hardening the flux. The heating is continued until a red heat is obtained, at which heat the solder will melt and "flush" or penetrate the joint. As soon as this stage in the process is reached the heat is withdrawn and the work quickly plunged into cold water. This has the effect of breaking up the flux and scale which can then be easily removed.

Silver Solders may be obtained in sheet, strip or granular form, with melting points varying between 1,250° F. and 1,500° F.

The usual composition of silver solders is 60% silver, 30% copper and 10% zinc. Another variety consists of 80% silver and 20% copper. Many other alloys are used with the silver content ranging from 5% to 50%.

Silver solders are particularly useful for the uniting of monel metal, nickel steel and stainless steel, as the whiteness of the joint makes it difficult to distinguish from the original metal. Specially coloured solders are sometimes used by jewellers in order that joints made in such metals as platinum and gold will not be noticeable.

Aluminium Soldering : Most aluminium castings can be repaired quite satisfactorily by welding with the oxy-acetylene process, but often it is unwise to heat certain castings to the heat required for welding as this may result in distortion. It is necessary, therefore, in such cases to find some means of uniting the parts without heating them to a high temperature. This can be done, and a permanent repair made by soldering when the solder can be made to adhere to the aluminium, and the joint not afterwards subjected to corroding influences.

The parts to be joined must first be "tinned," and as aluminium cannot be soldered with a hot, copper soldering bit, it is necessary to use an atmospheric gas torch or kerosene blow-lamp, and follow a procedure somewhat similar to brazing, with the exception that no flux is used. The surfaces to be joined must first be heated to a temperature above that of the melting point of solder and then rubbed and scratched with a tinned steel tool to remove the outside film and any oxides that may be on it, thus giving the solder a clean surface to act upon. The higher the temperature at which the tinning is done the better will be the adhesion. After the surfaces to be joined have been properly tinned they can be joined by pressing the parts together and applying sufficient heat to melt

the solder. Care must be exercised to ensure that there is no movement of the work until the solder has cooled and set.

Soldered joints in aluminium should not be exposed to moisture as galvanic cells are set up within the joint and will rapidly cause it to disintegrate as a result of auto-corrosion.

Aluminium Solders : A solder consisting of tin and zinc is suitable for the joining of aluminium with proportions ranging from 20% zinc and 80% tin to one with 50% zinc and 50% tin. Two other compositions containing aluminium in addition to tin and zinc have been found satisfactory. They have the following proportions:—

(a) 10% zinc ; 5% aluminium ; 85% tin.

(b) 15% zinc ; 10% aluminium ; 75% tin.

Protection of Aluminium : Aluminium and aluminium alloys can be effectively protected from atmospheric corrosion by the application of a good quality varnish, enamel or bitumastic solution to the surface.

Questions :

1. Compare brazing and soft soldering.
2. What is spelter ?
3. What is the value of borax as a flux ?
4. Name the chief sources of heat used for brazing.
5. What is meant by silver soldering ?

WELDING.

Welding may be defined as the process of uniting metals, similar or dissimilar, in a state of fusion.

Classification: There are two classes of welds, viz.

(a) Autogenous
(b) Heterogeneous.

(a) **Autogenous Welding** is the term usually employed to denote the joining, in a state of fusion of two similar metals.

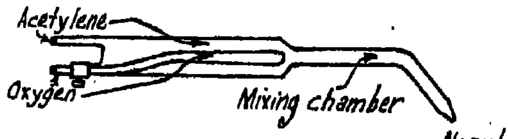
(b) **Heterogeneous Welding** is the uniting in a state of fusion of dissimilar metals or where a dissimilar metal is used as a uniting agent.

There are many different methods of welding, chief among which are:—

(a) Fire welding	(d) Oxy-coal gas welding
(b) Oxy-acetylene welding	(e) Thermit welding
(c) Oxy-hydrogen welding	(f) Electric welding

(a) **Fire Welding:** Is a very ancient practice, confined chiefly to iron and steel. The weld is made by heating the two pieces to be joined to a welding heat in a fire, bringing them together and hammering quickly and energetically. The fluxes used in this process are white sand, sal-ammoniac and borax. The details of joints and heats necessary for fire welding are dealt with more fully in the chapter on "Forge Work."

(b) **Oxy-acetylene welding:** Is a fairly modern process carried out with the aid of a blow-pipe or blow-torch. This is an instrument in which the oxygen and acetylene gases combine to support a flame at the exit nozzle, which flame is projected on to the metals to be welded.



DIAGRAMMATIC ARRANGEMENT OF OXY-ACETYLENE BLOWPIPE.

Blow-pipe welding, as such, dates back many years. The Egyptians, Greeks and Romans used primitive blow-pipes for the autogenous welding of metals with a low melting point, such as lead. It was not, however, until the industrial manufacture of oxygen that a flame with a temperature hot enough to melt metals with a high melting point was produced.

The oxygen used in this process is compressed into steel cylinders each fitted with a valve for the release of the gas.

Acetylene gas was discovered in 1836 by Humphrey Davy. It is produced by the action of water on carbide of calcium, a stone-like substance containing 6.25% calcium and 37.5% carbon, and may be manufactured directly in a generator or procured compressed in steel cylinders. As acetylene can be dissolved in acetone these cylinders are filled with a porous substance, *e.g.*, granulated charcoal or textile fabric saturated with this liquid and the gas then forced in under pressure. One cubic foot of porous material will absorb approximately 100 cubic feet of acetylene gas.

The temperature of the oxy-acetylene flame measured at the extremity of the white jet is approximately 7,000° F. and is therefore capable of quickly melting any ordinary metal.

Fig. 1. Characteristics of the Oxy-acetylene flame.

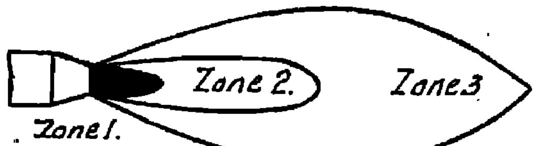
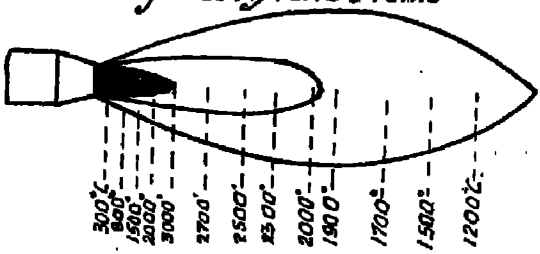
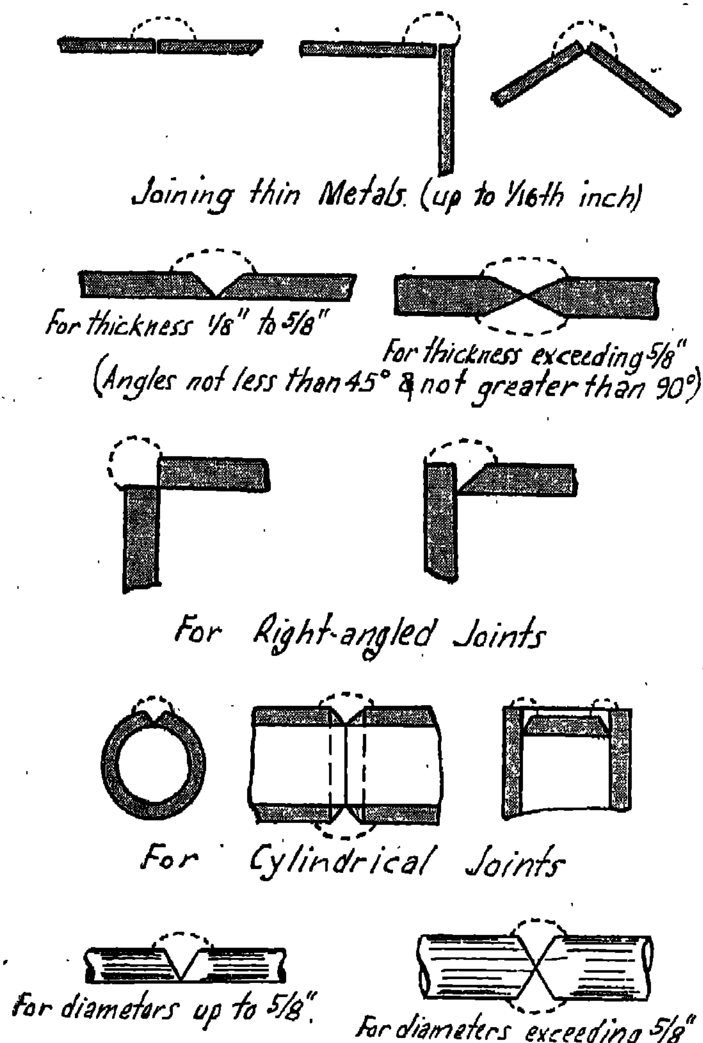


Fig. 2. Temperatures in the oxy-acetylene flame



The joint generally used for this type of welding is the butt joint, but where the metal is of a thicker gauge the edge of each piece is bevelled off so that when butted together, a V-shaped groove is formed. The joint is heated with the "torch" and the metals made to fuse together, a welding rod being used in the process to fill in the groove and so unite both sides of the joint. **The Welding Rods** used should be of good quality and suitable to the metals being welded, *e.g.*, for iron and steel, good quality rods of Swedish iron are procurable. These are free from sulphur, phosphorus and manganese and other harmful ingredients. For the welding of brasses the rods should consist of very pure metal with the addition of a small percentage of aluminium to help deoxidise the weld. For the welding of aluminium the rod must be of pure aluminium without impurities of any kind, particularly copper as the slightest trace of this metal will render a joint in aluminium susceptible to the action of water and moist air.



PREPARATION OF WELDS.

Fluxes: For blow-pipe welding, fluxes are many and various, and are produced commercially to suit almost any metal. A good flux that can be used during the welding of cast-iron is composed of equal parts of carbonate and bi-carbonate of soda, 15% borax and 5% precipitate of silica.

Cutting Metals: The oxy-acetylene process is also extremely useful for cutting off pieces of iron and steel or cutting out holes, etc. The process is very similar to that of welding except that a special cutting torch is used, which, when the flame has reduced the metal to a red heat, allows a jet of oxygen to impinge on the heated portion, with the result that it is converted into molten iron oxide. This oxide is driven away as it is produced, allowing the process of cutting to extend through the thickness of the metal.

(c) **Oxy-hydrogen Welding:** This process is older than that of oxy-acetylene, being first introduced for industrial purposes in 1901. A blow-pipe is also used with this method but the temperatures produced are not as high, being approximately 4,000° F. Consequently, a lot of the heat is absorbed and lost by conductivity. The chief uses of this method are the welding of thin ferrous metals and lead burning.

(d) **Oxy-coal Gas Welding:** This method was introduced in 1838 and again employs a blow-pipe. A flame is produced by the combustion of a mixture of coal gas and oxygen. It is used chiefly for brazing thin metals or making joints in lead and is not to be recommended for welding joints that are likely to be subjected to any strain.

(e) **Thermit Welding:** Is used for welding joints in iron and steel where the metal is very thick, consequently it is the method generally employed for uniting railway and tramway rails and for the repair of large iron or steel castings. It consists of burning a mixture of powdered aluminium, iron oxide and steel scrap.

This mixture is usually fired by means of a strip of magnesium. The temperature of combustion is very high, being approximately 5,400° F. At this temperature the aluminium unites with the oxygen to form alumina, leaving the iron free to combine with the molten steel scrap and cement the joint, the sides of which have been brought to a welding heat as a result of the high temperature created by combustion. Joints to be united in this way are generally packed around the outside with fire-clay or some other heat-resisting substance.

(f) **Electric Welding :** More and more uses for this process are being found every day. Nevertheless, it seems that there will always be a place in the workshop for the oxy-acetylene blow-pipe, as in many ways these two methods supplement each other.

There are two types of Electric Welding :—
(1) Resistance Welding ; (2) Arc Welding.

(1) **Resistance Welding :** Is the method used in the manufacture of large quantities of small or specialised articles by machinery. Some types of resistance welds are :—

(a) Butt Weld	(c) Spot Weld
(b) Contact Weld	(d) Seam Weld

(a) **Butt Weld :** The two ends to be joined are butted together and electric current sufficient to bring both edges to fusing point passed through them. At the moment of fusion the ends are pressed together and consequently united.

(b) **Contact Weld :** This process is used largely in the manufacture of wire mesh for fencing, concrete reinforcing, aircraft emergency landing strips, etc. The wires are laid out in the desired pattern and a current passed through, causing them to fuse at the points of contact.

(c) **Spot Weld :** Two pieces of thin metal are lapped one over the other and a current passed through the metals at points along the joint. This has the effect of fusing both pieces at these points of contact, and consequently uniting them. A joint of this type is somewhat similar to a riveted joint, but is not as strong.

(d) **Seam Weld :** To achieve this weld, the seam is run through a machine having two rollers, one of which is on top of the seam, the other underneath. The current passes from one roller through the seam to the other, and in so doing, fuses the metals in between. The process is much similar in effect to that of spot welding with the exception that with the seam weld, the fusing is continuous throughout the length of the seam. This method is used extensively in the manufacture of light metal articles, toys, etc.

Note.—It is necessary with resistance welds to ensure that the surfaces to be united are perfectly clean, as the presence of any oxide or dirt reduces the solidity and strength of the joint.

(2) **Arc Welding :** Is the system of electric welding most generally used. It is achieved by holding a carbon rod or a metal electrode in a pair of tongs and allowing the current to pass through to the work. As the electrode is held a little distance away from the work, an arc is created between them, the heat of which causes both the work and the electrode to melt.

The localisation of the heat is not favourable to perfect welding, therefore it is necessary to find a satisfactory flux to keep the joint clean and free from oxides. Some electrodes can be procured with a covering of the particular flux necessary for their use ; with others it is necessary to procure the correct prepared flux.

With electric arc welding, as with oxy-acetylene, the edges of the joint are usually ground away to form a V-groove, thus providing a greater surface of contact for the uniting metals.

Questions :

1. Define the process of welding.
2. Name the *two* classes of welds.
3. What instrument is used in the oxy-acetylene welding process to project the flame ?
4. What use is made of the Thermit welding process ?
5. Name the two types of Electric welding.

METAL WORK

SHEET METALS.

The metals used by the sheet metal worker, for various purposes, may be conveniently divided into four groups, viz. :—

1. Ferrous metals.
2. Covered or "tinned" metals.
3. Pure metals.
4. Alloyed metals.

1. Ferrous Metals : The chief sheet metals in this group are Mild Steel and Stainless Steel :—

(a) *Mild Steel* : These sheets are often referred to as black iron sheets; they have a black or bluish oxidised surface and are malleable, ductile and tenacious. They are used in the manufacture of tinplate, galvanised iron, motor bodies, stove pipes, metal ceilings, and can be obtained in lengths ranging from 6 to 8 feet, widths from 24 to 36 inches and thicknesses from 30 (B.G.) to $\frac{3}{16}$ of an inch.

(b) *Stainless Steel* sheets have a bright silvery surface that will take and hold a very high polish. They are malleable, ductile, tenacious, will resist corrosion and can be welded or silver soldered. These sheets are used for bench coverings and sinks in kitchens, laboratories, etc., and for dairy, hospital and brewery equipment as they are unaffected by most acids and will not contaminate foodstuffs.

2. Covered Metals : The sheet metals in this group are galvanised iron, tinplate and terneplate.

(a) *Galvanised Iron* is sheet mild steel (black iron sheets) coated with zinc. It has a bright silvery surface and is easily distinguished by the large, crystalline spangles on its surface.

By reason of the ability of zinc, with which these sheets are covered, to resist corrosion by the atmosphere, galvanised iron is very suitable for outdoor constructional purposes, such as roofs, tanks and downpipes, also for the making of tubs, buckets, etc.

Galvanised iron sheets are manufactured in gauges, measured by the Birmingham Gauge (B.G.), ranging from 10 to 30-gauge (corresponding to ⅛-inch and 1/80-inch respectively), and in lengths ranging from 5 to 12 feet, with widths from 24 to 48 inches.

(b) *Tinplate* is sheet, mild steel or iron, coated with tin. It has a bright, silvery sheen. It is used mainly for the packing of foodstuffs such as jams, fruits, fish, as the tin coating does not contaminate the contents. Many cooking and household utensils are made of tinplate. It is of little or no use for outdoor or constructional purposes as damp air soon causes it to corrode.

Tinplate sheets are obtainable in various sizes and thicknesses, the most common sizes being 28 × 20 inches and 20 × 14 inches, with thicknesses 1C and 1xxx (No. 1 Three Cross), corresponding approximately to 30 and 26-gauge (B.G.) respectively.

(c) *Terne Plate* is sheet mild steel coated with lead. It is bluish grey in colour and is used mainly as a substitute for galvanised iron and for the manufacture of petrol tanks, petrol drums and paint tins. The process of manufacture of terne plate is practically the same as for galvanised iron but its ability to resist corrosion is not to be compared with the latter metal.

(d) *Aluminium Plate.* The process of coating steel with aluminium is a discovery of recent years. It is made in sheet and wire form and will withstand much higher temperatures than tin or zinc coated steel, it may be brought to a white heat of 1800°F. and maintained at that heat for 1,000 hours without deterioration. This metal combines the high resistance of aluminium to corrosion and acids with the high tensile strength of steel and is used in motor car and aircraft construction, house furnishings and industrial machinery.

3. Pure Metals: The chief metals in this group used commercially for making into sheet form are copper, zinc, lead, tin and aluminium.

(a) *Copper* is reddish-brown in colour, and its utility depends largely upon its resistance to corrosion, its ductility and its malleability, this last property allowing it to be readily hammered or rolled into required shapes. It is a very good conductor of heat and electricity and so is used largely for electrical and heating apparatus. By reason of its ability to take a high polish, it is also used for ornamental and general repoussé work.

(b) *Zinc* is a white metal with a greyish tint, which, when new, has a greasy feel. It is malleable, moderately flexible and resists corrosion better than most other metals. It is used for making pipes and in the construction of batteries for generating electricity.

(c) *Lead* is a bluish-grey colour with a greasy feel. It is heavy, soft and malleable and one of the best metals for resisting corrosion. It is used largely by plumbers as a structural material for roofing purposes, damp courses, pipes and general sanitation work. On account of its mineral acid resisting properties, it is formed into vessels for holding these liquids.

(d) *Tin* is silvery-white in colour with a yellow tinge. It is very soft and malleable and has very little use in sheet form except for electrical condensers, and, as tinfoil, for the wrapping of sweets and foodstuffs.

(e) *Aluminium* is a silvery-grey colour, is malleable, ductible and very light. It is a good conductor of heat and does not readily corrode. This metal is used for making cooking and general household utensils, aeroplane and motor-car bodies, and for other purposes where lightness combined with strength is required.

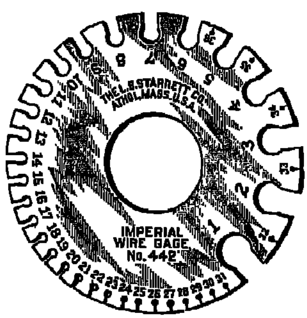
4. Alloyed Metals: The sheet metals in this group are of the copper-zinc, i.e., brass, variety, being formed by the combination of varying proportions of these metals.

(a) *Brass*, containing 80% copper and 20% zinc, is a fine yellow colour and is very malleable, possessing much the same qualities as copper.

(b) *Muntz Metal*, containing 60% copper and 40% zinc, is yellowish in colour and, on account of its high proportion of zinc, almost entirely resists corrosion and is, therefore, largely used for sheathing the bottom of boats.

Both of the above metals will take a high polish. They are used in the making of electrical appliances, for repoussé and general ornamental work.

Note : Both copper and brass tend to harden quickly when hammered or beaten with a mallet, making it necessary to anneal them frequently. This is done by heating to a dull red colour and quenching in water. They are just as effectively annealed, however, if allowed to cool slowly, but the use of water for quenching often means a considerable saving of time.



WIRE GAUGES

Gauging Sheet Metals : The thickness of sheet metals is usually referred to as the gauge; this is tested by using a small metal tool known as a Gauge, which has slots let into the edge, each representing a different thickness. Iron or steel sheets, whether black, galvanised or tinned, are measured by the Birmingham Gauge (B.G.). Note : 10 B.G. equals $\frac{1}{8}$-inch, and for every addition of six to the gauge number, the thickness is halved, *e.g.*,

16 B.G. would equal $\frac{1}{16}$-inch. Copper and brass are measured by the Imperial Standard Wire Gauge; and lead and zinc by the Lead and Zinc Gauges respectively.

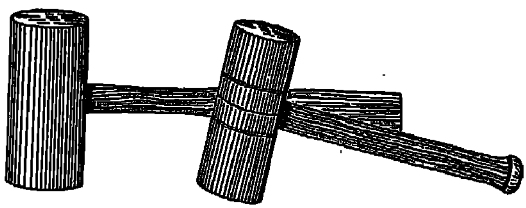
Questions:

1. What is meant by covered, pure and alloyed metals?
2. Name and state the uses of two covered metals.
3. Name and state the uses of three pure sheet metals.
4. Name and state the use of one alloyed sheet metal.
5. How is the thickness of sheet metals gauged?

THE MALLETS.

Mallets are used by the sheet metal worker for bending and forming his materials, by such operations as flattening, folding and bossing. As the use of a steel hammer would be likely to mark or injure the surface of soft sheet metals, such as tinplate, copper and brass, it is preferable to use a mallet for this purpose, bearing in mind the fact that, even a mallet, if carelessly handled, can considerably damage or bruise these metals.

There are two main types of mallets in everyday use in the metal work room, namely, the Flat-faced mallet and the Egg-ended or Bossing mallet.

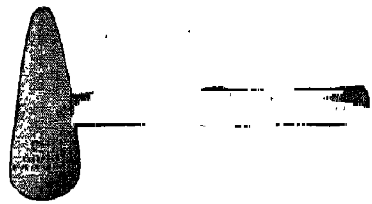


FLAT-FACED MALLETS.

The Flat-faced Mallet is used for flattening, curving and bending straight seams and edges, and for working on flat surfaces. This type can be obtained with the head ranging in size from 1½ inches to 3 inches in diameter, and is commonly made of boxwood, hide or hard rubber, fitted with a handle of cane or hickory. Hide and rubber mallets are preferred for more delicate work as, being of a softer nature, they are not so apt to injure the material being worked. The tendency for the mallet to split is also eliminated.

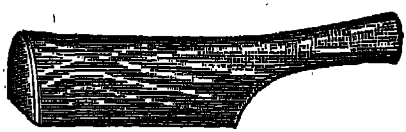
The Egg-ended or Bossing Mallet is, as its name implies, used for bossing, i.e., raising portion of a flat surface; and for hollowing or dishing sheet metals, *e.g.*, a bowl.

This type of mallet is made of boxwood, is turned in the



BOSSING MALLET.

lathe and has one end of the head larger than the other, giving the tool a wider range of usefulness. A useful size for general purposes is one with a maximum head diameter of $2\frac{1}{4}$ inches.



TINSMITH'S DRESSER.

The Tinman's Dresser, also used by the sheet metal worker, has a flat face and a rounded back; and is mainly used for flattening and shaping sheet lead, e.g., for roofing purposes and around chimneys, etc.

SUMMARY.

Classification: Percussion or shaping tool.

Types: There are two principal types :—

1. Flat-faced mallet.
2. Egg-ended or Bossing mallet.

Parts: Head, handle and wedge. The head is made of boxwood or hide, the handle preferably of cane or hickory and the wedge of some suitable hardwood.

Uses: The flat-faced mallet is used for working on flat surfaces and straight edges, and the bossing mallet for curved or "domed" surfaces, *e.g.*, a bowl.

Mallets are preferred to hammers for working on soft sheet metals as they are not so apt to bruise or injure the surfaces during the operations of folding, bossing, etc.

Questions:

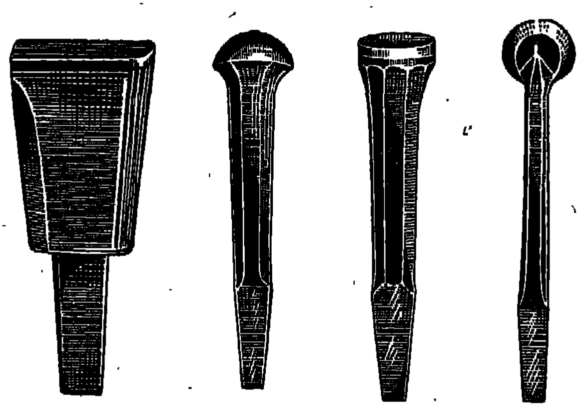
1. Name two types of mallets.
2. State the uses of both types.
3. Name the parts of the mallet.
4. Why are the handles made preferably of cane or hickory?
5. Why are mallets preferred to hammers for the working of thin sheet metals?

THE STAKES.

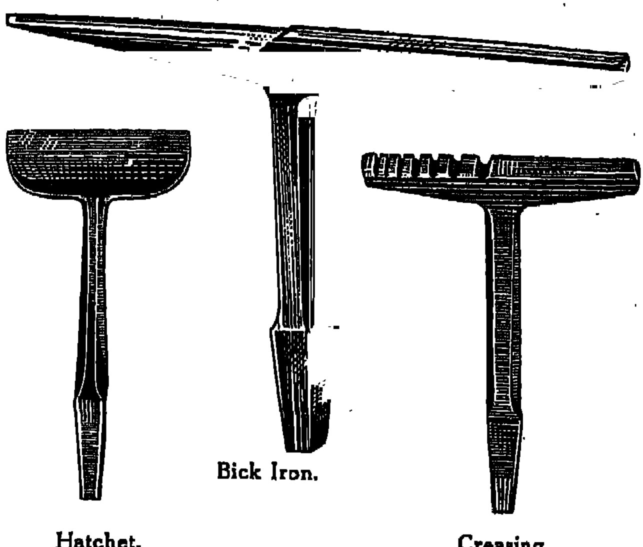
Stakes are used by the sheet metal worker for forming and bending such sheet metals as tinplate, galvanised iron, copper, lead, etc.

Stakes are made of cast or mild steel, with hard cast steel working faces, the shanks are tapered at the bottom to enable them to fit into holes or sockets in the bench. They may also be clamped in the vice if necessary. When shaping metals on a stake a mallet should always be used and not a hammer, as the latter would mark or injure the surface and ruin it for further work.

There are many *types of stakes* in use, each having been designed for one or more special purposes, for example :—



Tinman's Anvil. Round Head. Round Bottom. Half Moon.



TYPES OF STAKES.

The Tinman's Anvil is used to straighten surfaces, for planishing, and for forming edges.

The Bick-iron (sometimes called the *Beak-iron*) is used for general purposes and for working rectangular, cylindrical and conical objects.

The Square-headed stake is used for bending edges at right angles, setting up square bottoms and for finishing seams.

The Creasing stake or *iron* is for forming wired edges, working beads or grooves on flat surfaces and for countersinking seams.

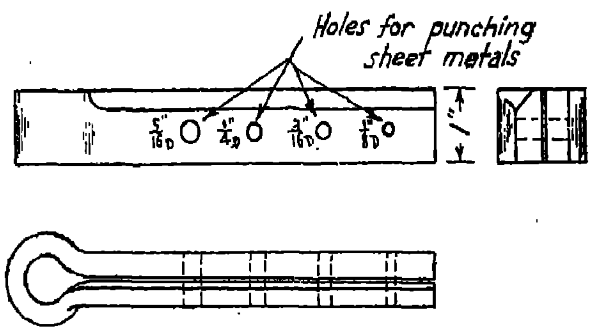
The Hatchet stake, as its name implies, has a sharp edge; it is used for forming acute angles and bending edges prior to grooving seams, wiring or folding.

The Funnel stake is so called on account of its shape and is used mainly for working conical objects.

The Half-moon stake is used for edging " capped on " bottoms in conjunction with the round-bottom stake, for closing wired edges and forming acute angles.

The Round Bottom stake is useful when edging circular bottoms and for finishing and straightening the bottoms of cylindrical objects.

The Round-headed, or Ball stake, is used for shaping or working on hollowed and concave surfaces.



FOLDING BAR.

The Folding Bars might also be included under this heading. They are used for folding and bending sheet metals and can be obtained with various sized holes, through which, with the aid of punches, holes can be made in the metals.

Questions :

1. From what materials are stakes usually made ?
2. Why are mallets used instead of hammers when shaping metals on a stake ?
3. Write down the names of four different stakes.
4. State their uses.
5. State the uses of the Folding Bars.

SEAMS, JOINTS AND EDGES.

Seams or joints are used by the metal worker for holding or binding his work together. In this he is aided by the use of rivets and bolts, or by the processes of brazing or soldering, the last-named being the simplest and the one most generally used for the joining of thin sheet metals. Before joining metals, however, it is necessary to so place the edges that the joint will be as neat and effective as possible.

Four common methods of placing edges for soldering are as follows :—

The Lap Seam, in which the two pieces are simply lapped one over the other.

Countersunk Lap Seam is the same, in principle, as the lap seam, but has a smooth surface on one side, formed by countersinking or setting down one edge.

The Double Lap Seam, where two pieces are "butted" together with a separate cover strip placed over them.

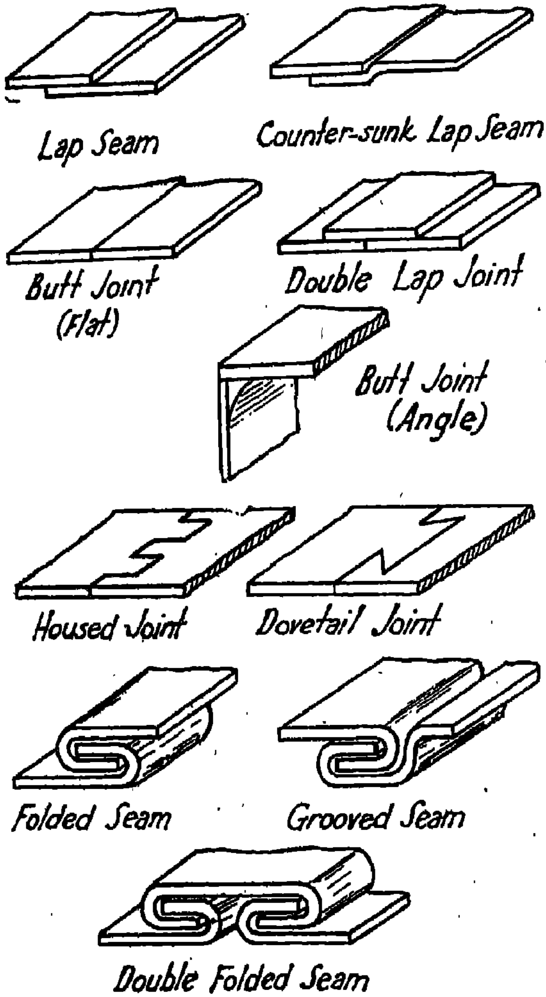
The Butt Joint, which may be either straight or angular in form, has the two pieces of metal placed together without lap or seam. This is not considered reliable as a soldered joint, and, to be of any practical value, should be silver-soldered or brazed.

Soldered seams, although commonly used and very convenient, are not considered to be very strong or reliable. The two following joints are the ones commonly used for the process of brazing or hard soldering :—

Housed Joint has the two pieces of metal fitting into each other at right angles, so offering greater joining surface. This type is used for joining thin plates.

Dovetail Joint has the two pieces dovetailed into each other as shown ; it is used when joining thick plates.

A stronger type of seam, used on thin metals, which may be soldered if required, is the folded type, wherein the metals are hooked together and so tend to tighten when strain is applied. Some of these are as follows :—



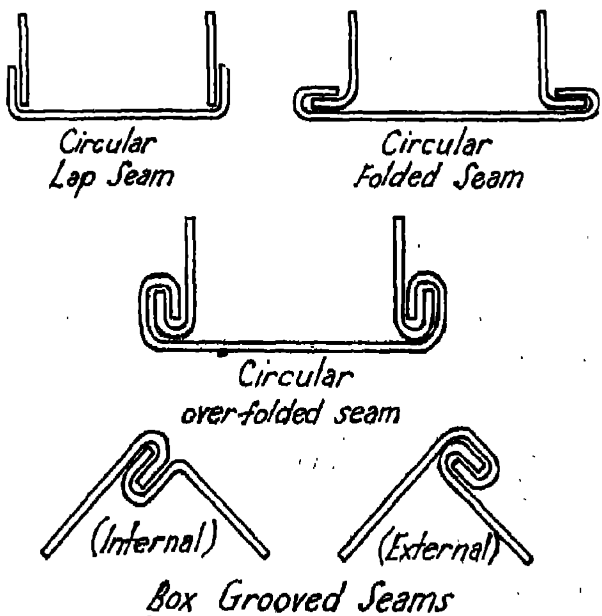
TYPES OF SEAMS.

The Folded Seam has two simple folds hooked together; it is a strong and serviceable joint.

The Grooved Seam is the same, in principle, as the folded seam, but is "set down" or countersunk, on one side, to give a smooth surface on the other.

The Double Folded Seam also has an unbroken surface on one side and is used when the plates are too thick to be countersunk or grooved.

The above three seams are generally used for articles or vessels designed to hold liquids and, when well made, are quite water-tight. This principle of the folded seam is also used in circular work, *e.g.*, the bottoms of galvanised iron tanks, baths, etc. When used in this way they are referred to as *angle seams*, and are as follows :—



TYPES OF ANGLE SEAMS.

Circular Lap Seam is a type of angle seam on the principle of the simple lap seam and is used for the bottoms of cylindrical objects.

Circular Folded Seam is used for cylindrical bottoms, *e.g.*, the bottoms of corrugated iron tanks. It is sometimes called the "paned down" seam.

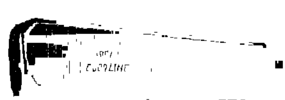
Circular Over-folded Seam is the "paned down" seam "knocked up." This is a very reliable joint which is absolutely water-tight and which is used on the bottom of cisterns, baths, etc.

Box Grooved Seam is another type of angle seam used mainly for corners. It is a strong seam and is usually made with the fold on the inside.

GROOVER.

Groover or Seam Set: This is the tool used for closing folded seam joints. The edges of the groover should be slightly rounded otherwise they are liable to cut or injure the metal on each side of the seam.

Riveted Seams: Sometimes it is necessary to rivet sheet metals, although this method is usually reserved for joining plates too thick to be folded or soldered. The tool used for this purpose is known as a rivet set.

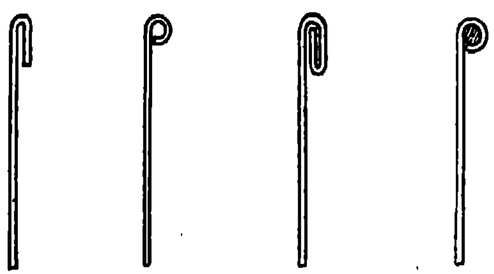


RIVET SET.

One point to remember before commencing riveting is that, when marking out the holes, the amount of "lap" (i.e., the distance from the centre of the hole to the edge of the metal), in the case of lap seams, must not be less than three times the diameter of the rivet. After marking the holes, the pieces to be joined are placed in position, one

over the other, and the holes punched through. For this operation the work should be placed in some firm position, with a thick piece of sheet lead immediately underneath, so that the punch may pass right through the plates.

Upon inserting the rivets, it will be noticed that the metal plates are slightly burred and not fitting closely round the shank of the rivet; to overcome this the "drift" or "bolster" portion of the rivet set, is placed over the rivet and hammered to close the plates about it and to bring them firmly together. The shank of the rivet is then hammered down, preferably with a ball-paned hammer, and finished off by neatly rounding with the "snap" portion of the rivet set.



TYPES OF FINISHED EDGES.

Finishing Edges: There are four main methods of finishing edges in common use, viz.:—

The Wired Edge—this is the best method and the one most commonly used for the tops of drinking vessels, dippers and such like. The edge is first folded over on the hatchet stake, the amount of fold being a little more than twice the diameter of the wire. When the fold has been prepared, the wire is placed in position and the metal carefully closed around it with a mallet. The edges are then "tucked" in with a small, straight paned hammer, after which the whole length is straightened out on the

creasing iron with the aid of a mallet. If the object being made is to be circular in shape when finished, *e.g.*, a billy-can, the edge is wired in the flat and afterwards curved as desired.

The Single Folded Edge is the simplest of the edges and is made by marking off the amount of fold, bending sharply on the hatchet stake and then finally flattening down and straightening with the mallet.

The Beaded Edge is similar in construction to the single folded edge, except that it is worked round instead of being flattened. It has the appearance but not the strength of a wired edge.

The Double Folded Edge is similar to the single folded edge, with the addition of a second fold the same width as the first and on the same side.

SUMMARY.

The seams and joints commonly used in sheet metal work may be conveniently divided into two groups, viz., Flat Seams and Angle Seams, and are as follows :—

Flat Seams :

Lap Seam—two pieces of metal lapped over each other.

Countersunk Lap Seam—is similar in principle to the lap seam, but has a smooth surface on one side.

Double Lap Seam—two pieces "butted" together with a cover strip. The above joints may be either soldered or riveted.

Housed Joint—two pieces of metal fitted into each other at right angles; it is used when brazing thin metals together.

Dovetail Joint—has the two pieces dovetailed together and is used when joining thick plates by brazing.

Folded Seam—two folds hooked together; this is a strong, dependable seam.

Grooved Seam—same principle as the folded seam, but is "set down" to present a smooth surface on one side.

Double Folded Seam—also presents a smooth surface on one side and is used when joining thick plates.

The folded seams are generally employed on vessels used for holding liquids.

Angle Seams:

Circular Lap Seam, Circular Folded Seam, Circular Over-folded Seams—are used for the bottoms of cylindrical objects.

Box-Grooved Seam—is used mainly for corners, and usually is made with the seam on the inside.

Finishing Edges: The four chief methods of finishing edges are, viz.:—

Wired Edge—when the edge is rolled over with a piece of wire on the inside.

Single Folded Edge—when the edge is simply folded over and flattened down.

Beaded Edge—is somewhat similar to the folded edge, but is rounded instead of being flattened.

Double Folded Edge—similar in construction to the folded edge, but with two folds instead of one.

Questions :

1. Sketch and name three "flat" seams.
2. Sketch and name three "angle" seams.
3. Describe two methods of finishing edges.
4. What is the use of the Groover ?
5. What is the use of the Rivet Set ?

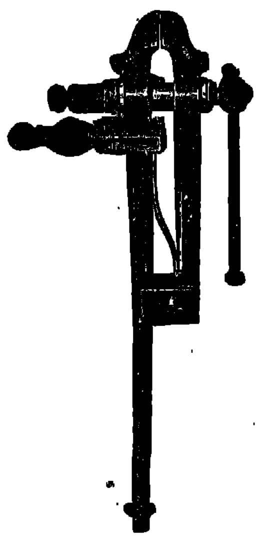
THE ENGINEER'S VICE.

A vice is one of the most necessary and useful items of the engineer's bench equipment. There are many different types and patterns, but most of these may be classified, for convenience, under one of the two following types :—

(a) The Leg Type.

(b) The Parallel Type.

(a) **The Leg Type :** This is the older type of vice and the one usually found in blacksmiths' shops and where

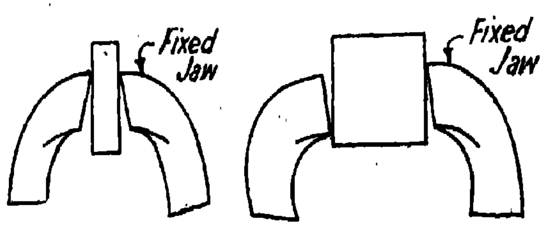


LEG VICE.

heavy work is done. It is made of wrought-iron or mild steel, the jaws being faced with hard-cast steel. It consists of two jaws, the shorter one being attached by a hinge to the longer one. The jaws are forced apart by a spring, placed between the legs, and are adjusted by a

handle which turns a screw working in a long nut called the box. This vice has a leg or standard which is fixed either to the bench leg or to the floor. The vice is attached to the bench by bolts passing through the horn which projects across the top of the bench and which is screwed down to it.

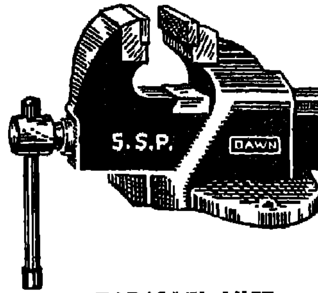
The leg vice grips tighter and is better able to withstand heavy work, such as chipping or cold bending, than the lighter type of vice. It has, however, one serious disadvantage, arising from the fact that the loose jaw, working on a hinge, must always move in the arc of a circle. This means that, when the jaws are closed, they grip at the



DEFECTIVE GRIP OF LEG VICE.

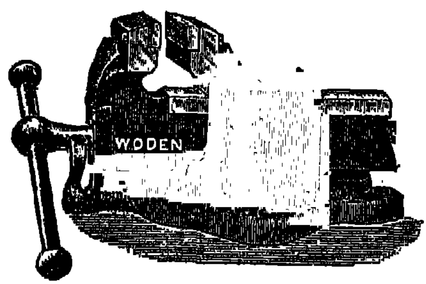
top rather than at the bottom, and when widely open, only grip the work with the lower edges; moreover, the tops of both jaws are no longer level, consequently the work does not remain in a plane parallel with the top of the bench, which may seriously interfere with the operator's judgment as to the truth of the surface on which he is working.

(b) **The Parallel Vice:** This is designed to overcome the above fault in the leg vice. The jaw forms part of a sliding box, so that the gripping surfaces of the jaws always remain parallel. The vice is generally made of cast-iron or semi-steel, fitted with cast steel face pieces screwed to the jaws. The adjusting action is similar to that used in the leg vice.



PARALLEL VICE.

Instantaneous Grip Vice—There is in use a type of parallel vice fitted with a spring lever device, known as the "Instantaneous Grip" or "quick release" type. By means of this arrangement, much time is saved in adjusting, as the jaws of the vice are free to be moved quickly in or out, simply by pressing a small lever at the front end of the



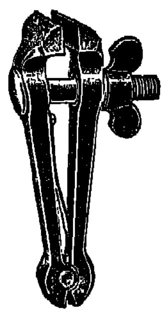
"INSTANTANEOUS GRIP" VICE.

vice which causes the half-nut to be disengaged from the screw. By releasing the lever and giving a single turn to the screw handle the work is securely gripped by the jaws.

Vices are measured by the width of the jaws and are available in widths varying from $2\frac{1}{4}$ inches to 8 inches, although, in general workshop practice, widths of $3\frac{1}{2}$ inches and 4 inches are found to be most suitable. The spacing

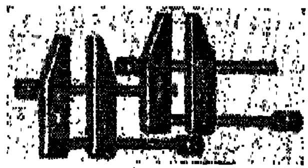
of vices on the bench is important; the distance between centres should not be less than 3 feet 6 inches to give the operator freedom of movement.

Height of the Vice: The height of a vice should be such as to allow the elbow of the worker to touch the top of the jaws. It is better to have a vice too high rather than too low, as the latter position compels the worker to stoop, bringing about early fatigue which may interfere with the production of good work. A good average height for the vice, from the floor, is 44 inches.



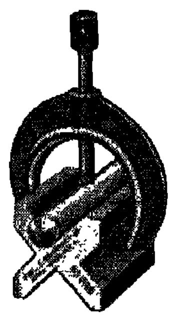
HAND VICE.

The Hand Vice: It often happens that small articles, such as screws, nuts, small pieces of metal, etc., cannot be held conveniently or with sufficient firmness by the hand. In such cases, a hand vice will be found most useful, for it will grip the work securely, allowing at the same time almost as much freedom as if the work were held by the hand itself. The most common type of hand vice used is constructed on the principle of the leg vice, that is, there is a spring between the legs and the jaws are adjusted by turning a wing-nut on a threaded screw which opens or closes them as required. There is also a parallel type of hand vice obtainable which is adjusted by hand pressure and then locked with a small screw device.



TOOL MAKER'S CLAMPS.

Tool Maker's Clamps: These clamps are made of steel, case-hardened, and are very useful for holding small work when tapping, drilling, etc.

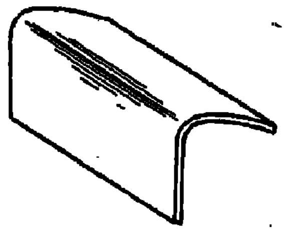


DRILL CLAMP AND BLOCK.

Drill Clamps and Blocks: These clamps, in conjunction with the drill blocks, are used for holding pieces of round material for the purpose of prick punching, drilling or laying out a series of holes before and while being drilled.

Vice Clamps: The jaws of the vice are faced with hard cast steel face pieces, roughened or serrated like a file, to grip the work securely. It is obvious, therefore, that delicate or finished work, or work of a soft nature, would be damaged by these roughened jaws. It is necessary, then, to protect the work from them while at the same time retaining the holding power of the vice. This is done by using vice-clamps, which are usually of some soft metal, such as brass, copper or lead, about $\frac{1}{16}$-inch thick. These

are made by taking two pieces of material large enough to completely cover the serrated face pieces and overlap sufficiently to turn back over each shoulder with a mallet.

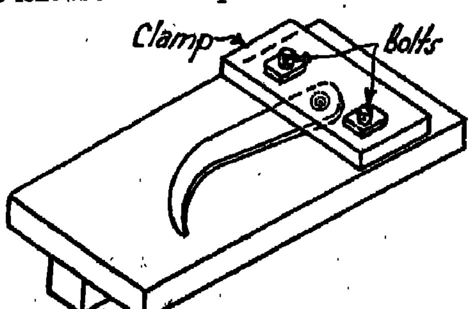


VICE CLAMP.

If well shaped, they will retain their position when the work is removed for inspection. Vice clamps are sometimes made of two pieces of wood hinged together by a piece of leather.

Filing Board: Sometimes a flat piece of work is too thin or irregular to be gripped by the jaws of the vice, in which case it is convenient to use a filing board. A simple method is to grip a piece of wood in the vice and attach the work to its face by small sprigs or panel pins which are driven in close around it and just below the surface; the material may then be worked upon as required.

A better method, however, is to construct a filing board as follows:—Take a piece of wood, about 8 inches



FILING BOARD.

by 5 inches and 1 inch thick, and screw to its underside another piece, the full length and about 1 inch square section; this is for clamping the board in the vice. A third piece of wood, 2 inches by $\frac{1}{2}$ inch and 5 inches long, is now taken and attached to the upperside of the large piece by means of two $\frac{1}{4}$-inch diameter carriage bolts; it may be stiffened by screwing a thin strip of metal to the top side. This top-piece acts as a clamp when the work is placed between it and the large piece and the nuts on the carriage bolts tightened with a spanner.

SUMMARY.

Classification: Gripping or holding tool.

Types: There are two main types of vices, viz.:—

1. The Leg Vice.
2. The Parallel Vice.

1. **The Leg Vice:** This is the older type of vice and is the form most generally used in places where heavy work is done. It is made of wrought-iron or mild steel, the jaws being faced with hard cast steel. The disadvantage of this type is that the loose jaw moves in the arc of a circle, consequently the work is not always gripped squarely; this may interfere with the operator's judgment as to the truth of the surface he may be working upon.

2. **The Parallel Vice:** This type is designed to overcome the abovementioned fault in the leg vice. It is made of cast-iron or semi-steel, with cast steel face pieces screwed to the jaws, and is constructed in such a way that the gripping surfaces always remain parallel.

There is a type of parallel vice known as the "Instantaneous Grip"; its advantage lies in the saving of time and greater convenience when fixing work.

Height of Vice: The height of a vice should be such as to allow the elbow to touch the top of the jaws when the arm of the operator is bent with the hand upwards. A good average height from the floor is 44 inches.

Vice Clamps: As the jaws of the vice are generally serrated, vice clamps must be used to prevent delicate work from being damaged or marked. Vice clamps are made of soft sheet metals such as brass, copper or lead, cut to the length of the jaws and bent so as to fit closely over the shoulder of each.

Filing Board: When a piece of metal is too thin to be held in the vice it may be fastened down on to a filing board with panel pins, or by a small piece of wood, acting as a clamp, which is tightened on to the work by means of bolts and nuts, the board being then clamped in a vice.

Questions:

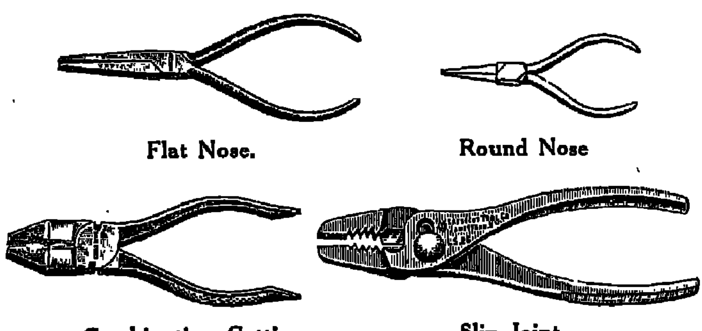
1. For what manner of work is the leg vice preferable ?
2. What is the great disadvantage of this type ?
3. What is a convenient height for a vice ?
4. When are vice clamps used ?
5. What is the function of a filing board ?

THE PLIERS.

Pliers of various types are always to be found in a metalworker's and an engineer's workshop, and are among the most useful of these artisans' tools. They are usually made of cast steel, with the inside of the jaws serrated in a manner similar to a vice, in order that they may secure a firm grip on the work.

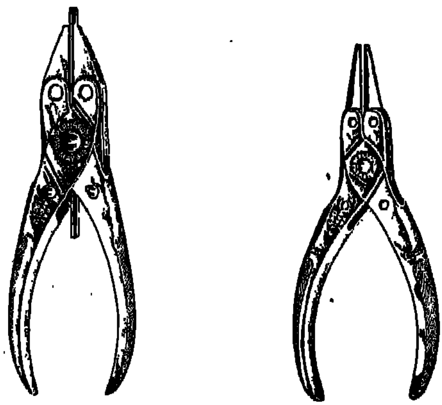
The most common and useful types are as follows:—

1. Flat-nose pliers.
2. Round-nose pliers.
3. Combination cutting pliers.
4. Slip-joint pliers.
5. Gas or Pipe pliers.



TYPES OF PLIERS.

Many other types of pliers can be obtained, each designed for some special purpose. One very good principle, characteristic of the more modern types of Flat and Round-nosed pliers, is that of parallel-grip action in the jaws, which means that, instead of the back of the jaws tending to grip the work first, the jaws move with a parallel motion, so bringing the whole length of the jaws into contact with the work at the one time.



PARALLEL JAW PLIERS.

Pliers may serve many different purposes, but the chief uses may be briefly enumerated as follows :—

1. For holding pieces of metal in position when they are being soldered, drilled or riveted.

2. For holding metals when they are being heated, or being worked while hot.

3. For bending or shaping wire or strip metal.

4. For cutting wire.

5. For gripping circular objects, *e.g.*, pipes. This last function is confined almost entirely to the combination, gas and slip-joint pliers, which are designed with this type of work in view.

Note : The pivot or joint of the pliers should be kept well oiled and free from acids, as the latter corrode the metal, so preventing a free and easy action.

Questions :

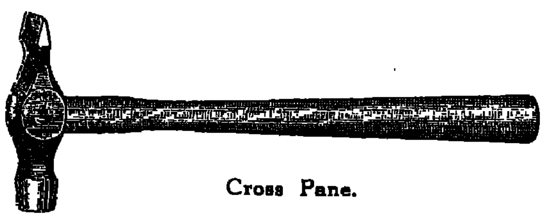
1. Name three types of pliers.
2. From what materials are pliers usually made ?
3. What is the use of the serrations inside the jaws ?
4. Write down three uses of pliers.
5. Why should pliers be kept well oiled ?

THE HAMMERS.

The hammer is amongst the oldest of the engineer's tools. Although there are many different shapes and sizes in use to-day, the hand hammers most commonly used are the following three :—

1. The Ball pane.
2. The Cross pane.
3. The Straight pane.

Ball Pane.



Cross Pane.

TYPES OF HAMMERS.

Hand hammers have three main parts: the head shaft and wedge.

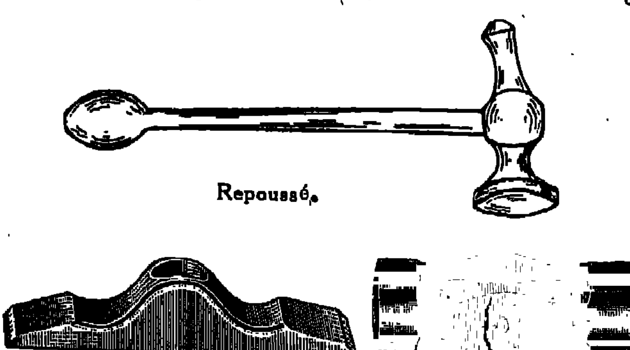
1. **The Head**: This is made of the best crucible cast steel and includes the face, eye and the pane; the face and the pane are hardened and tempered to prevent them becoming distorted, through use on hard metals. The centre portion, which includes the eye, is left soft to withstand shock and absorb the force of the blow. The eye itself is elliptical in shape and tapers from both ends towards the centre, for the purpose of securing the shaft.

2. **The Shaft**, or handle, is usually made of hickory, ash or spotted gum; the timber used should be straight-grained and free from knots.

3. **The Wedge** may be either wood or steel. When made of steel it should be suitably barbed, so as to grip the wood of the handle when driven into it.

It will be noticed, in the design of the hammer heads, that the main difference is in the pane, the centre portion and the face ends being almost identical in each case. It is therefore safe to assume that the difference in the pane has a definite bearing on the use of the hammer; this is so, *e.g.*, the ball pane, being more suitable for spreading the material, is used for riveting purposes and for bossing, scarfing, etc. The Cross pane, which runs at right angles to the axis of the hammer shaft, is also used for riveting, but usually where the rivet is in a recess. This type is used extensively by the sheet metal worker, being suitable for working sheet metals in spaces so small that the use of the mallet is prohibited. When forming wired edges, for example, it may be used instead of a paning hammer for closing the metal around the wire.

Three other types of hand hammers designed for special purposes are the Repoussé, the Paning, and the Planishing hammer. The Repoussé hammer, used for the making



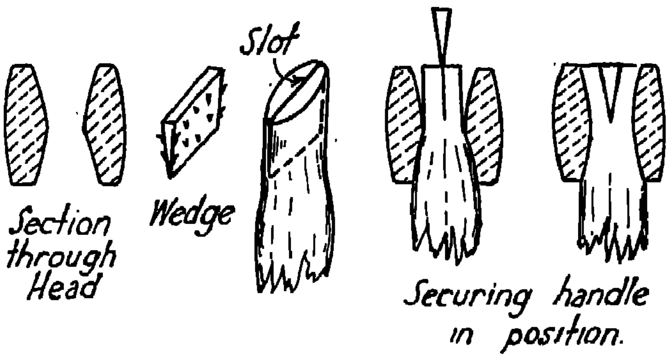
Repoussé.

Paning. Planishing.

TYPES OF HAMMERS.

of light models, *e.g.*, ash trays, from sheet copper, brass, etc., has a very wide face and a small ball pane. The Paning hammer has two sharpened cross panes, for working on folded seams and for closing the metal around the wire in wired edges. The Planishing hammer has two flat faces and is used for planishing and flattening surfaces.

Fitting the Handle: The handle should be tapered with a rasp until it fits into one side of the eye; a saw cut



METHOD OF SECURING HAMMER HANDLE.

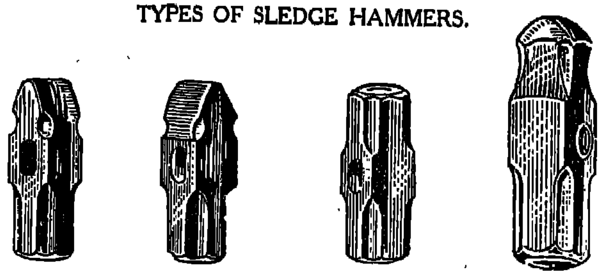
is then made along the grain of the timber and the handle driven through to the other side, making sure that it is at right angles to the axis of the head. The wedge is inserted into the saw cut and driven home. This has the effect of spreading the wood of the handle, so that it completely fills the eye, thus firmly locking the handle in position.

Using the Hammer: When using a hand hammer, the handle should be firmly grasped and the fall of the head should be in the arc of a circle and of even weight, care being exercised to see that the face of the hammer is flat when it comes into contact with the work, otherwise the "edge" of the face may seriously damage the surface of the metal. It is also advisable to make sure that the face of the hammer is free from oil or grease.

Sledge Hammers: These heavy hammers are usually found in blacksmith or boilermaking shops and are

made in four shapes, viz., Ball pane, Straight pane, Cross pane and Double-faced. They are fitted with long handles and are swung double handed.

TYPES OF SLEDGE HAMMERS.



Straight Pane. Cross Pane. Double-faced. Ball Pane.

Hammers are graded or specified by the weight and pattern of the head; hand hammers ranging, in general practice, from about $\frac{3}{4}$lb. to $1\frac{1}{4}$lbs., and sledge hammers from about 2 to 6 lbs. in the lighter, and up to 28lbs. in the heavier types.

Note: There are several different spellings for the word **pane**, viz., pane, pein, pene and peen, but of these, the first mentioned is most commonly used. Irrespective of the spelling, however, "pain" is generally accepted as the pronunciation.

SUMMARY.

Classification: Percussion or impelling tool.

Types: There are three principal types of hand hammers, viz.:—

1. Ball pane.
2. Cross pane.
3. Straight pane.

Parts: Head, shaft and wedge.

The head is made of cast steel. It has three parts—the face, eye and pane. The face and pane are hardened and tempered, but the centre portion is left soft to withstand shock. The eye is elliptical in shape and is tapered from both ends towards the centre for the purpose of securing the shaft.

The handle is usually made of hickory or spotted gum, which should be straight grained and free from knots.

The wedge may be either of wood or steel.

Uses: Hammers are used in all branches of engineering for general purposes such as the straightening, chipping, riveting, etc., of metals.

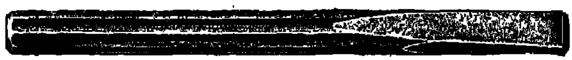
Both hand hammers and sledge hammers are graded or specified by the weight and pattern of the head.

Questions:

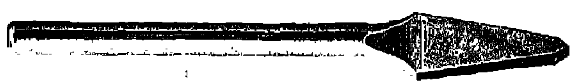
1. Name the principal types of hand hammers.
2. Name the parts of the hammer.
3. From what materials are these parts made?
4. How would you fit a hammer shaft?
5. How are hammers specified?

THE COLD CHISELS.

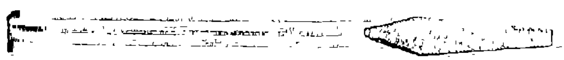
Cold chisels are classified as cutting tools and are so named and classified because they are used for cutting and working on cold metals. In general engineering practice these chisels are made from cast steel, approximately 1 inch in diameter, the steel usually being octagonal or oval in section and about 8 inches long. In the metal work room they are usually forged from ½ inch octagonal cast steel and range from 6 to 7 inches in length.



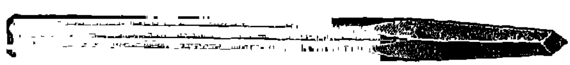
Flat.



Cross-cut.



Round-nose.



Diamond-point.

TYPES OF COLD CHISELS.

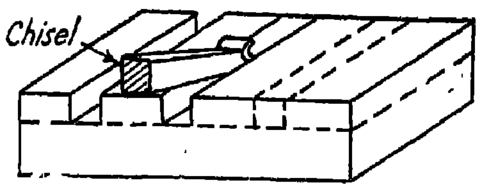
There are four main types in common use, viz.:—

1. The Flat chisel.
2. The Cross-cut chisel.
3. The Round-nose chisel.
4. The Diamond-point chisel.

1. **The Flat Chisel**: Has a broad cutting edge, usually about 1 inch wide, ground slightly convex to overcome the tendency of the corners to dig into the work. This general utility chisel is used for chipping surfaces, reducing them to given dimensions, cutting thick sheet metals and for cutting lengths from rods and bars. For cutting

cast-iron, especially light cutting, the edge may be thin, but for cutting mild steel the edge should be stronger, as more strength is required to bend the cuttings.

2. **The Cross-cut Chisel**: Has a narrow cutting edge, usually about ¼ or ⅜ of an inch in width, with the tapered portion shaped so that the width diminishes for an inch or so just above the cutting edge to allow clearance when working in a groove. This chisel is used for cutting



"BREAKING UP" A SURFACE.

grooves and keyways; also when chipping large areas, it is used for the purpose of "breaking up" the surface, that is, a series of parallel grooves are cut across the metal to facilitate the reducing of the whole. These grooves are the width of the cross-cut chisel and are slightly less in distance apart than the width of the flat chisel which is to be used for removing the remaining high portions.

3. **The Round-nose Chisel**: Is used for smoothing out corners in castings, for cutting concave or semi-circular oil grooves in flat surfaces, or in bearings when it must be bent to a suitable radius, also for the purpose of "drawing-over" holes, which, at the commencement of drilling, have moved off-centre.

4. **The Diamond-point Chisel**, as its name implies, has a diamond-shaped face. It is used for cutting small V-shaped grooves, for cutting out or cleaning square corners, for squaring drilled holes, and for roughening surfaces, such as steel steps for stairways.

Cutting Angles of Chisels: Chisels for cutting metals differ from wood chisels in that they have much thicker cutting edges, this being necessary on account of the greater resistance offered by the materials on which they are used. The angle formed by the facets, i.e., the cutting angle, varies in accordance with the particular metal to be chipped. For instance, the cutting angle of a chisel to be used on steel would have to be broader than that of a chisel to be used on copper or lead.

Suitable cutting angles for various metals are set out in the table below:—

METAL TO BE CUT	CUTTING ANGLE
Cast Steel	60 to 70 degrees
Cast Iron or Brass	50 „ 60 „
Wrought Iron or Mild Steel	40 „ 50 „
Copper or Gunmetal	30 „ 45 „
Aluminium, Babbit Metal, Lead, Zinc ...	25 „ 30 „

Note: The angle of the cutting edge of a chisel used for general purposes is usually taken as 60°.

Using the Chisel: When chipping, the chisel should be held as close to its head as possible; this gives steadiness, which, in turn, tends to protect the user's hand. The cutting edge should be kept hard up against the work and the force of the blow regulated so that it will not be forced out of its cut; also the chisel should be kept at a constant angle, with the eyes of the operator concentrated on the cutting edge. The weight of the blows should be even and the rate about forty per minute, the

hammer shaft being held as near the end as possible. Care should also be taken to see that the face of the hammer and the end of the chisel are free from oil or grease.

HOLDING THE CHISEL No. 1.

HOLDING THE CHISEL No. 2.

Lubrication : When chipping wrought-iron, mild steel or other tough metals, lubricate the cutting edge by rubbing it on a piece of oily waste or by dipping in soapy water.

SUMMARY.

Classification: Cutting or reducing tool.

Types: There are four main types of chisels in common use :—

Flat,
Cross-cut,
Round-nose,
Diamond-point.

Parts: Head, body, taper and cutting edge.

Uses: **The Flat Chisel** has a broad cutting edge and is used for all general purposes, *e.g.*, cutting thick sheet metals, reducing surfaces to dimensions and for cutting rods, bars, etc.

The Cross-cut Chisel has a narrow cutting edge, and the taper is shaped to allow for clearance when cutting. It is used for cutting grooves and keyways ; for "breaking-up" surfaces prior to finishing with the flat chisel.

The Round-nose Chisel is used for smoothing round corners in castings, for cutting semi-circular oil grooves and for "drawing-over" holes which have moved off-centre when drilling.

The Diamond-point Chisel is used for cutting V-shaped grooves, for squaring round holes or corners and for roughening surfaces.

Note: The cutting angle of a chisel varies in accordance with the metal being worked, but, in general practice, an angle of 60° is found to be satisfactory; this angle may be reduced with advantage when working on softer metals.

Questions:

1. Name the four main chisels.
2. Name the parts of the chisel.
3. State the material from which chisels are made.
4. What is the cutting angle of a chisel for general use ?
5. When may this angle be reduced with advantage ?

FILES AND FILING.

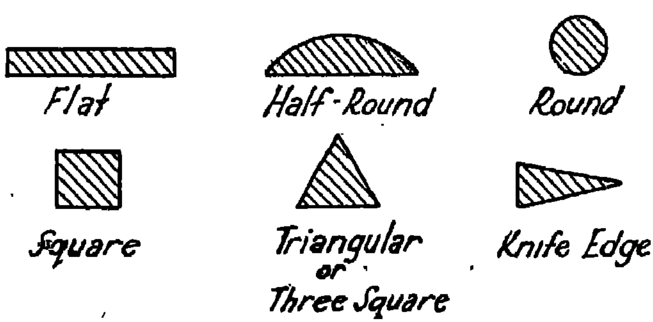
Files are among the most important of the engineer's hand tools; it is necessary, therefore, that he thoroughly understand, not only their use, but also something about their construction and the types made, so that he may be better able to choose the particular files which will help him to produce his best work.

These tools are made from the best high-grade tool steel, forged to shape, cut and carefully tempered, and, whereas formerly made by hand, are now produced by machinery. Files are usually distinguished by the three following characteristics :—

1. Length.
2. Shape (i.e., sectional form).
3. Cut.

1. **Length :** The length of a file is measured from the shoulder to the tip, i.e., exclusive of the tang. It varies in general practice from about 3 to 20 inches, but the lengths most commonly found in the workshops are from 10 to 12 inches, for general work, and from 6 to 8 inches for work of a finer nature.

2. **Shape** (sectional form) : Files are made in a variety of sectional forms, each designed to meet the requirements of some particular kind of work. The following are the most usual forms :—



SHAPE OR SECTION OF FILES.

(a) *The Flat File* is the one most generally used for flat or convex surfaces and can be obtained either single or double cut; although the latter is the cut most frequently used, the teeth on the edge are always single. Flat files can be obtained in all lengths and grades, suitable for coarse or fine work. Some have teeth on one edge only; these are known as "safe edge" files and are so made that one side of an internal angle may be filed close up to the adjacent side without injury to the latter.

"*Hand*" *Files* are a type of flat file. They have one "safe" edge and are slightly "bellied" (convex) across the faces, to enable the operator to bring his file to bear exactly upon a particular spot without injury to any other part, also they are parallel throughout their length but taper slightly in thickness towards the tip.

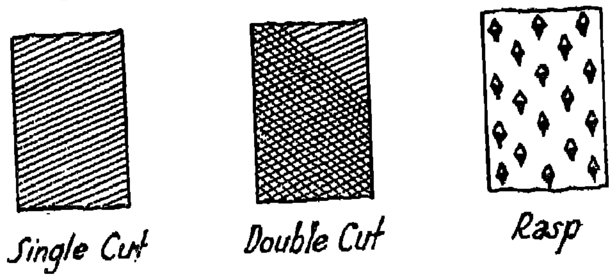
(b) *The Square File* is double cut on all sides and tapers towards the tip, although still retaining its square section. It is used for working in slots, etc., and for squaring holes.

(c) *The Half-round File* is really segmental in shape and tapers, both in width and in thickness, towards the tip. It is double cut on the flat face and single cut on the round, but the single cuts intersect, giving the appearance of double cutting. This file is used for concave work and for producing sharp corners.

(d) *The Round File* can be obtained parallel throughout its length, but it usually tapers towards the tip, when it is known as a "rat-tail" file. It is used for circular work, *e.g.*, trueing or enlarging holes.

(e) *The Triangular* or *Three-Square File* is equilateral in cross section, is parallel for about two-thirds of its length and then tapers to a point. It is used for dove-tailing, filing angles and sharpening saw teeth.

(f) *The Knife-Edge File* is triangular in section, with one very acute angle. It is double cut on the two wide faces and single cut on the edge, and is used for filing or cleaning out very acute angled corners.



CUTS OF FILES.

3. **Cut:** Files are generally divided into three groups according to their cuts, viz.:—

(a) Single-cut.
(b) Double-cut.
(c) Rasp.

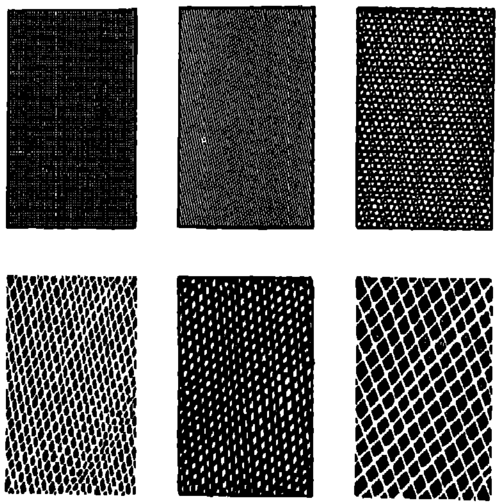
(a) *Single-cut*: These files are made with a single row of teeth, or cuts, set at an angle of 15° with the edge of the file. Single-cut files are used for working on very hard metals, *e.g.*, the sharpening of saws and knives.

(b) *Double-cut*: These are the most common type, having two rows of teeth, the first series cut at an angle of 40 to 50 degrees to the edge, and these overcut with another series, at the same angle as that of a single cut file, giving to the file, as a consequence, a diamond-shaped pattern.

Note: When made by hand, these rows of teeth were cut at the rate of 60 to 80 per minute, but with modern machinery they are now cut at rates ranging from 500 to 3,500 per minute.

(c) *The Rasp* has small independent cone-shaped teeth raised up on its surface. It is not used much by the metal worker, except on very soft metals, such as lead,

because on the harder metals the prominent teeth would soon be broken off and the tool rendered useless. They are mainly used by woodworkers and leather workers.



GRADES OF FILES.

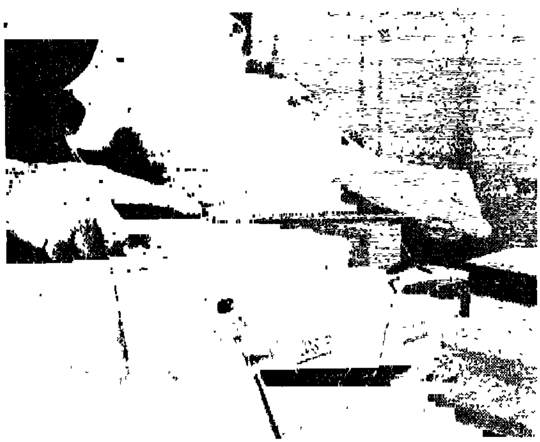
Grade: The grade of a file is dependent upon the cut meaning that the more cuts there are to the inch, the finer the file, and the less cuts, the coarser the file. There are six main grades, viz:—the Rough, Middle Cut, Bastard, Second Cut, Smooth and Dead Smooth with rows of teeth ranging from 22 to the inch, in the rough, to about 120 in the dead smooth. Experience has proved, however, that the Bastard, Second Cut and Smooth are sufficient for most general purposes.

Use of the File on Various Metals: Files which have been used on steel and wrought-iron will not cut cast-iron, brass or copper. It is advisable, therefore, to first use new files on these latter metals as they may then be afterwards used on steel or wrought-iron with very little loss of cut.

Note: Before using the face of a file, the edge should first be used to remove any dirt or scale which may be on the surface of the material.

Using the File: Filing is a very important operation and only after continued practice is the ability to file a surface perfectly smooth and plane attained. One important point to consider, in relation to filing, is the height of the work; this should be about the height of a worker's elbow; the work being firmly secured in the vice jaws and parallel to them with as little as possible showing above.

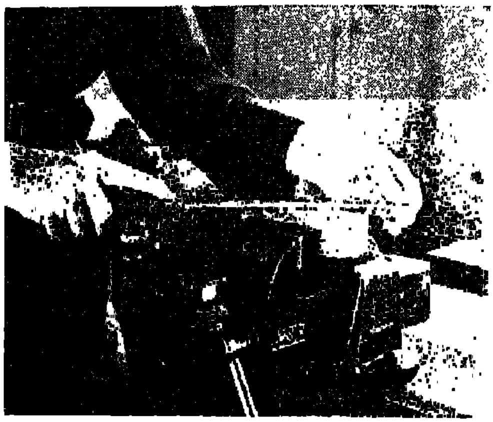
Holding the File: There is only one method of holding the file in the right hand, that is, the handle should rest in the palm of the hand, with the fingers around it, the index finger along the side and the thumb on top. There are three methods for the left hand:—



HOLDING THE FILE No. 1.

1. The palm of the hand resting on the tip of the file with the fingers grasping it firmly underneath. This method is used when a large quantity of metal is to be taken off.

2. The operator grasps the tip of the file between the thumb and forefinger, thumb uppermost, and the remaining fingers underneath. This method is used for lighter cuts and more delicate work.



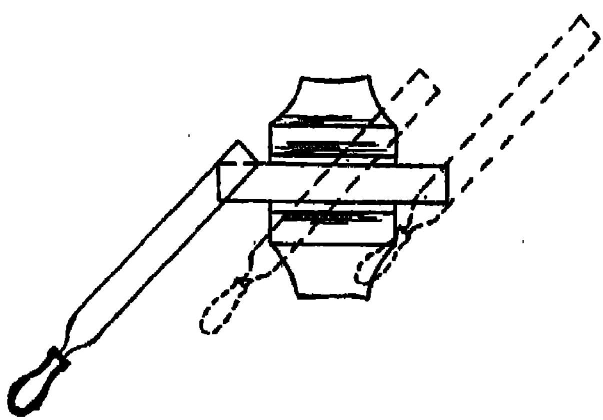
HOLDING THE FILE No. 2.

HOLDING THE FILE No. 3.

3. The operator spans the thumb and forefinger along the surface of the file, the point of the forefinger being at the extreme end. This method is used to overcome any tendency to "rock" the file on the work; also the whole length of the file can be brought into action.

Position: When filing, the operator should stand with the left foot in front of the right with the weight of the body thrown slightly forward. Above all, his position must be comfortable and free, to prevent undue fatigue.

Cross-filing is filing in the direction of the length of the file. The tendency to "rock" the file on the work is overcome, to some extent, by moving the file across the work at an angle of about 45° to it (see sketch), thus covering more of the surface with the file at the one time.



METHOD OF CROSS FILING.

The direction should be reversed frequently to prevent the formation of grooves. The surface of the work being filed should not be touched by the hands and should be free from oil and grease, as these cause the file to slip over the work and so retard the cutting.

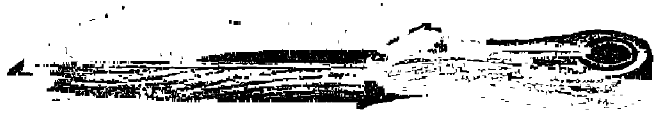
Draw-filing: When the work has been reduced by cross-filing to approximate truth, it is subjected to the

process of draw-filing to remove the marks left by cross-filing and to produce a smooth, even-grained surface. For this process a smooth file is grasped by both hands,

METHOD OF DRAW FILING.

the finger-tips holding the file on one side, with the thumbs on the other side, nearest the body. The file is then lightly pushed and drawn over the work, producing a series of fine parallel cuts along the surface.

Pinning: In the process of filing, small particles of metal get caught in the teeth of the file, causing it to slip over the work and to scratch it. This is termed "pinning," and is overcome, to some extent, by chalking the file,



FILE BRUSH.

but the most efficient method is to rub the file with a file brush and then to pick out any remaining particles with a sharp-pointed tool, *e.g.*, a scriber.

Polishing: After being draw-filed, the work can be still further polished by stretching a piece of emery cloth around the file and using it in a manner similar to draw-filing. After working through from coarse to fine emery cloth, a high polish is produced by placing a few drops of oil on the surface of the metal and rubbing it with the last piece of fine, worn emery cloth. This also protects the surface of the metal and helps it to withstand rust.

SUMMARY.

Classification: Reducing or abrading tools.

Parts: A file consists of three parts, viz., the body, tang and handle, the latter including the ferrule.

The body and the tang are made of high-grade tool steel, forged to shape, ground, and cut. The body is then hardened and tempered, the tang being left soft to withstand shock.

Files are distinguished by their length, shape (sectional form) and cut.

Length is measured from the shoulder to the tip.

Shape: There are six main shapes, or sectional forms, of files, viz. :—The Flat, Square, Half-round, Round, triangular or Three-square and the Knife-edge, each having its own particular uses. Some flat files have Teeth on one edge only and are known as "safe edge" files.

Cut: There are three different types of cut, the single cut, double cut, and rasp, the former two being used by the metal worker and the latter mainly by wood workers and leather workers.

Grade: Files are graded according to the relative coarseness or fineness of the teeth. There are six main grades, viz. :—Rough, Middle Cut, Bastard, Second Cut,

Smooth and Dead Smooth, with rows of teeth ranging from 22 to the inch in the Rough, to about 120 in the Dead Smooth. In general practice, the Bastard, Second Cut and Smooth are the grades most frequently used.

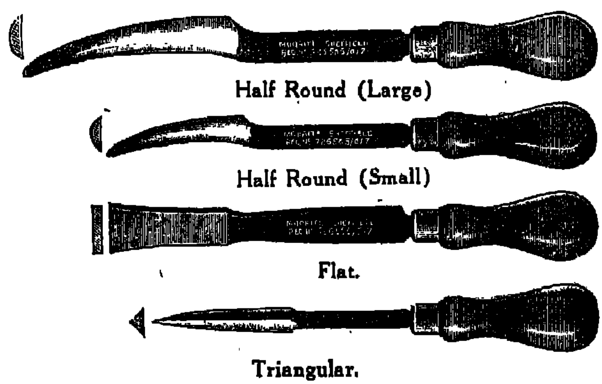
Questions:

1. How are files distinguished ?
2. Name the parts of a file.
3. Sketch and name four sectional forms of files.
4. What is meant by "pinning" ?
5. Explain what is meant by cross-filing and draw-filing.

SCRAPERS AND SCRAPING.

Scraping is a process used by the engineer for producing truer surfaces than can be produced by the ordinary filing and planing methods. It is necessary when plane surfaces are required to fit perfectly to each other and also when a frosted appearance is to be given to a finished surface without regard to its planeness.

The Scraper, including the handle, should be from 10 to 12 inches long, but this is controlled, to some extent, by the character of the work on which it is to be used. If too long it will be springy and will not give the best results.



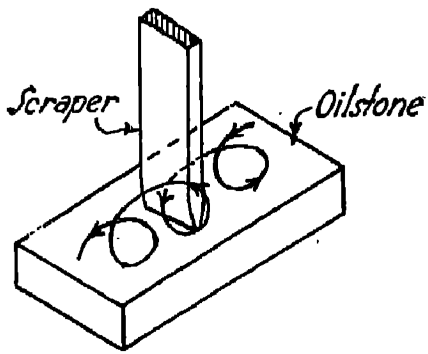
TYPES OF SCRAPERS.

The most common scrapers are :—

1. Flat.
2. Triangular or Three-cornered.
3. Half Round.

The first being used for flat surfaces and the latter two for curved surfaces. They are usually made from worn-out files. For example, the flat scraper can be conveniently formed from an old, smooth, flat file. The

file is drawn down so that the end is no thicker than $\frac{1}{16}$-inch and about 1 to $1\frac{1}{4}$ inches wide. The surfaces



METHOD OF SHARPENING A SCRAPER.

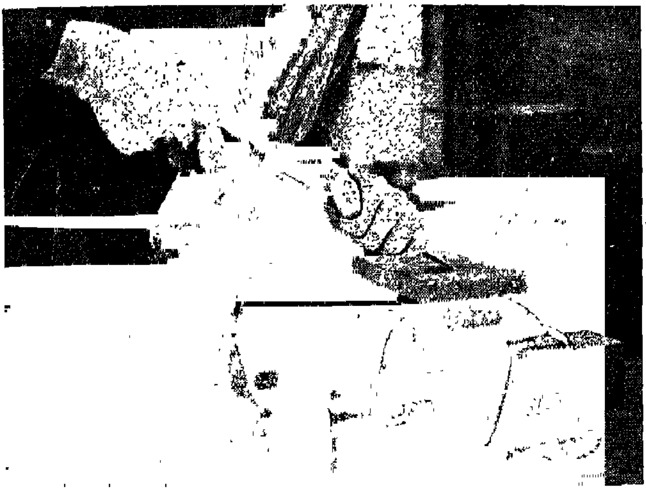
and cutting edge are then ground, with the edge at right angles to the surfaces. The edge should also be ground slightly convex to prevent it taking too broad a cut, as this tends to produce a wavy surface and prevents the corners digging into the work. The flat scraper should be sharpened by holding it upright on an oilstone and honing the edge with a circular motion as shown. After being sharpened, the tool may then be hardened. This is done by heating to a blood red colour and plunging into water.

All scrapers should be kept keenly sharpened by means of an oilstone. The keenness of an edge can be tested by trying it upon the thumb-nail, which it will pare, freely, if sharp.

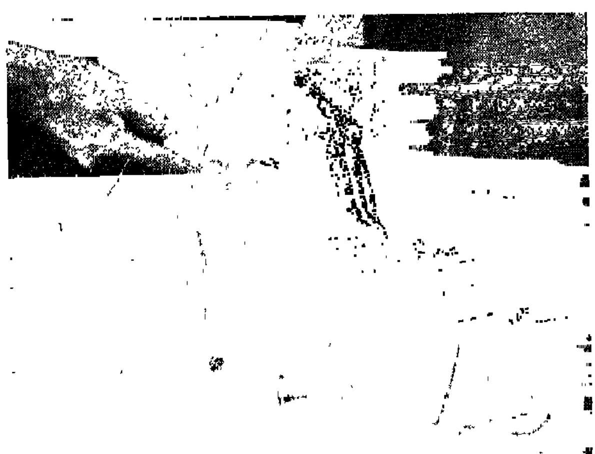
Holding the Scraper: The scraper should be held with the handle in the right hand, the thumb on top and the fingers underneath, the left hand grasping the body of the scraper with the back of the hand uppermost.

Using the Scraper: In scraping, short quick strokes are taken, the tool being pressed firmly to the work on the cutting stroke and eased on the backward stroke. The pressure required depends upon the hardness of the

ledge, being scraped and the condition of the cutting meta for, as the edge of the tool dulls, the pressure must be increased in order to give cuts of equal depth.



HOLDING THE FLAT SCRAPER No. 1.



HOLDING THE FLAT SCRAPER No. 2

TESTING: When scraping flat surfaces, a surface plate is used for testing. This is lightly smeared with "reddle," a mixture of red lead or oil, prussian blue and oil, or printer's ink of the right consistency. The work being scraped is rubbed on to the surface plate, or *vice versa*, if the work is of a heavy nature, when the high spots will show up as those covered with the reddle. The process of scraping consists in the removing of these high spots by scraping first in one direction and then in another and by frequently testing until the spots smeared with the reddle are distributed evenly and closely over the whole surface.

The Half-round and Three-cornered Scrapers are used for scraping bearings and large bushes, etc. The action, when using them, should be the same as when using the flat scraper, i.e., the strokes should cross one another and not follow continually in the same direction. When semi-circular work is being scraped, it is necessary to use a piece of shafting, or some such round material, for the purpose of testing. Good examples of truth of surface, obtained by scraping, are to be found on the surface plate and the beds of most lathes.

Questions:

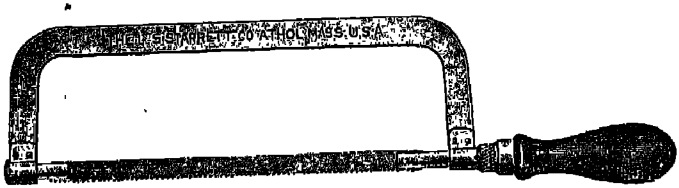
1. What is meant by scraping?
2. Name the three common forms of scrapers.
3. Why is the surface plate used in the process of scraping?
4. How would you harden a scraper?
5. Describe the common method of holding the scraper.

THE HACKSAW.

The saws used by the metal worker for severing his materials are known as hacksaws. They are used chiefly for cutting rods and bars to required lengths and thick sheet metals to required shapes.

A hacksaw consists of four main parts:—The frame, handle, tension screw and blade.

Frames are generally made of mild steel and can be obtained either fixed or adjustable, the former to take blades of one length, and the latter to take blades of varying lengths, usually from 8 to 12 inches. The advantage of the latter type, in this respect, is obvious.



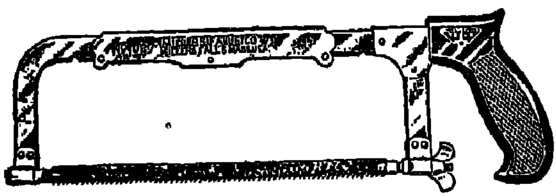
FIXED HACKSAW.

The frame of the hacksaw is fitted, at one end, with a wooden handle, and at the other with a tension screw and butterfly or wing nut. This tension screw is used for applying the necessary tension to the blade. In some hacksaws the tension screw is fitted into the handle, which acts as a nut, the tension being adjusted thereby.

Blades are usually about ½ inch wide and .025 inch thick. They are made from the very best cast steel, hardened and tempered. Blades can be obtained which are hardened and tempered on the cutting side only, the back edge being left comparatively soft. This prevents the blade breaking right through and may save the operator from possible injury. Blades can be obtained in lengths varying from 8 to 12 inches, with either coarse or fine

teeth. The teeth are set or " staggered " to allow clearance for the blade to move backward and forward through the work, without hindrance by friction.

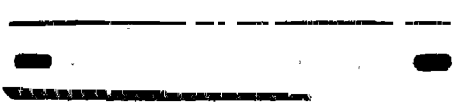
For general work, such as cutting mild steel, cast-iron and brass, blades with 16 to 20 teeth per inch are used;



ADJUSTABLE HACKSAW (WITH PISTOL GRIP).

for cutting annealed tool and spring steel, about 18 to 24 teeth per inch; for iron, mild steel, brass tubing, and thin sheet metals, blades with 24 to 32 teeth per inch will be found most suitable. For general usage in the workshop, however, a blade 10 inches long, with about 18 teeth per inch, is usually satisfactory.

Single Edge.



Double Edge.

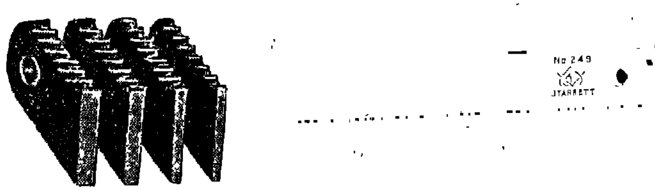
TYPES OF HACKSAW BLADES.

The following table suggests the number of teeth required per inch in blades for cutting certain materials by hand :—

MATERIALS TO BE CUT	NUMBER OF TEETH PER INCH
General work on Mild Steel in Rounds, Flats and Squares	18
Cast Iron and Tool Steels	18
Angle Iron, Brass, Copper, Iron Pipes and extra hard Steels	22
Sheet Metal, Thin Tubing, Conduit, Stainless Steel	32

Slotting Blades are designed for cutting slots in screw heads, etc. They are usually about 8 inches long, ½ inch wide, and are made in four different thicknesses, ranging from .049 to .109 inches. These blades are hardened throughout and taper in thickness from the teeth, which have no set, to the back, thus providing clearance, which prevents binding and allows the blade to cut easily and quickly.

SLOTTING BLADES



Holding the Hacksaw : It is very necessary that the saw be held and used correctly, if good work is to result. Many of the more modern hacksaws are fitted with pistol-grip handles. When, however, the handle is of the round,

horizontal type, the manner of holding in the right hand is similar to that used on the handle of a file; the hacksaw is steadied in front by the thumb and the first two fingers,

HOLDING THE HACKSAW.

the thumb inside and the fingers immediately underneath.

Using the Hacksaw: When using a hacksaw the number of strokes, for general work, should not exceed 50 per minute; but for cast-iron, annealed tool and spring steel, this number should be reduced and the pressure on the blade increased. The strokes should be steady and the full length of the blade should be utilized, as short, fast strokes draw the temper of the teeth and cause rapid wear.

As with other cutting tools, the hacksaw does better work when the pressure is sufficient to make the teeth cut freely, rather than to scrape the surface. The judgment of the operator must be used to determine what pressure to apply, as so much depends upon the work in hand and upon the varying conditions of the cut.

The blade should be set in the frame with the teeth pointing to the front end, so that the cut will be made on the forward stroke, with a releasing of the pressure on the return stroke. It should be strained with the tension screw until it rings when flipped with the thumb. Most hand frames are made so that the blade can be faced at right angles to its normal position for making deep cuts near the edge of the work.

For ordinary hand hacksaw work no lubricant should be used on the teeth, as this tends to make them slip over the metal, so decreasing their cutting efficiency. When, however, taking a deep cut in steel a few drops of oil, rubbed on the side of the blade with the fingers, will reduce friction and make the saw work more easily and cut more freely.

When cutting thin metals the saw should not be used at right angles to the surface, as this causes the load to fall upon too few of the teeth, consequently breaking them, but should be brought to bear on the work in a line parallel with, at a slight angle to, the surface, to bring more teeth into contact with the material at the one time.

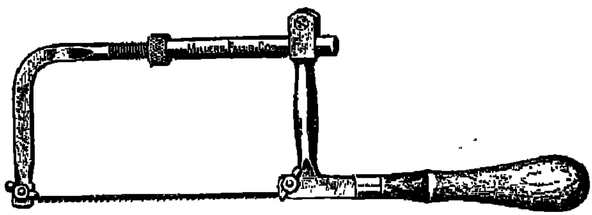
Wrong. Right.

CUTTING THIN METAL WITH THE HACKSAW.

The following are some factors which contribute towards broken blades and which must be carefully avoided :—

1. Work held insecurely.
2. Blade too loose in frame.
3. Too much pressure exerted.
4. Cutting thin metal with a coarse blade.
5. Unsteady or jerky movement of the hand.
6. Starting a new blade in a previous cut.

The Piercing or Jeweller's Saw is a smaller type of hacksaw used mainly for decorative work on the softer metals, although it can also be used on the harder metals when the work is of a very light nature. It is usually



PIERCING SAW.

about 5 inches long, with an adjustable attachment, which allows blades of varying lengths to be fitted into the frame, with the teeth set in the opposite direction to that used in the hacksaw, i.e., they point towards the handle, the cutting being done on the downward stroke, as shown.

USING THE PIERCING SAW.

SUMMARY.

Classification: Cutting and reducing tool.

Types: There are two main types in common use :—

1. Fixed.
2. Adjustable.

The fixed type takes blades of one length only, and the adjustable takes blades of varying lengths.

Parts: Frame, handle, tension screw and blade.

The frame is made of mild steel and the handle of hardwood, fitted with a ferrule. In some modern types the tension screw is fitted into the handle and adjusted thereby.

Hacksaw blades are made of a special saw steel, hardened and tempered. They are usually $\frac{1}{2}$ inch wide, about $\frac{1}{32}$ of an inch thick, and can be obtained with either coarse or fine teeth. The coarse have about 16 teeth per inch and are used for heavy work, *e.g.*, cutting solid bars. The fine have up to 32 teeth per inch and are used for lighter work, *e.g.*, cutting tubing and thin sheet metals. For general purposes, a blade 10 inches long, with 18 teeth per inch, has been found most suitable.

The number of strokes should not exceed 50 per minute. Cutting takes place on the forward stroke only, and so the pressure should be slightly released on the return stroke. No lubricant should be used on the teeth of the saw as this retards the cutting.

To Operate: Grasp the saw firmly in both hands, bear just hard enough on the forward strokes to cut freely and ease on the return stroke. Do not twist or jerk the blade, but maintain a steady stroke throughout.

Questions :

1. Compare the fixed type of hacksaw with the adjustable type.
2. Name the parts of a hacksaw.
3. State from what materials these parts are usually made.
4. What is the advantage of the soft back type of blade ?
5. Why is it not advisable to lubricate the work when using a hacksaw ?

MARKING OFF, MEASURING AND TESTING TOOLS.

The principal tools classified under this heading may be set out as follows :—

1.	The Steel Rule.	11.	The Feeler Gauge.
2.	„ Scriber.	12.	„ Radius Gauge.
3.	„ Centre Punch.	13.	„ Taper Gauge.
4.	„ Square.	14.	„ Screw Pitch Gauge.
5.	„ Bevel.	15	„ Drill Gauge.
6.	„ Angle Gauge.	16.	„ Calipers.
7.	„ Depth Gauge.	17.	„ Dividers.
8.	„ Plug Gauge.	18.	„ Scribing Block.
9.	„ Ring Gauge.	19.	„ Vee Blocks.
10.	„ Snap Gauge.	20.	„ Surface Plate.

As the Square, Dividers and Calipers may each be divided into several types, they will be dealt with under separate headings, following upon this main group.

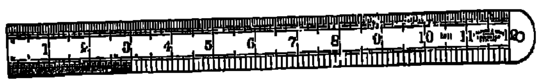
The tools set out above are used, as the heading states, for the purpose of marking-off, as well as for measuring and testing work in engineering shops. It might be as well, therefore, to understand at the beginning what is meant by the term "marking-off."

Marking-off is a workshop term used to denote the marking of lines, circles and centres on surfaces for the guidance of the engineer and metal worker. The production of accurate work depends largely upon the accurate and skilful use of the "marking-off" tools.

All guide work, such as lines, centres, etc., should be carefully located and checked, prior to beginning operations. To set the work out more clearly and to facilitate the process, the surface to be marked should be coated with a suitable medium. If the work is of a rough or temporary nature, it may be sufficient to rub it with chalk or to paint it with whitewash or kalsomine. For finer work, however, a copper-sulphate solution is very useful. This solution consists of one ounce of copper

sulphate, four ounces of water and a few drops of nitric acid, the latter being added to cause the solution to " bite " slightly into the surface.

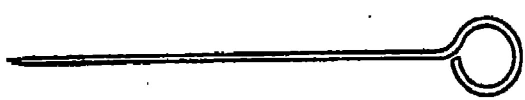
Before this solution is applied, it is necessary to see that the surface to be coated is free from oil or grease, otherwise the treatment will be ineffective. When applied, the copper sulphate changes the surface to a dull copper colour on which scribed lines show clearly and distinctly and are not easily rubbed off.



12" STEEL RULE.

The Steel Rule, or Straight Edge, is made of tool steel and can be obtained in lengths ranging from 1 inch to 72 inches. The most common size found in the workshop is one 12 inches long by about $1\frac{1}{8}$ inches wide and $\frac{1}{32}$ inch thick. It is usually graduated to 16ths of an inch throughout its length, with the first three inches further graduated to give 32nds and 64ths of an inch. Both edges are parallel throughout and, with reasonable care, will remain perfectly true.

Uses: This tool is used for measuring distances, as a standard when setting calipers or dividers, for marking straight lines in conjunction with the scriber and for testing the truth of plane surfaces.

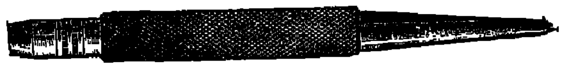


RING SCRIBER.

The Scriber is often referred to as the metal worker's pencil. It is made of tool steel, hardened at the pointed end. Scribers are obtainable in many designs, the most common being a slender piece of tool steel, formed into

a ring or eye at one end and sharpened to a fine point at the other; this point is hardened sufficiently to scratch other metals, and when dull should be sharpened on an oilstone.

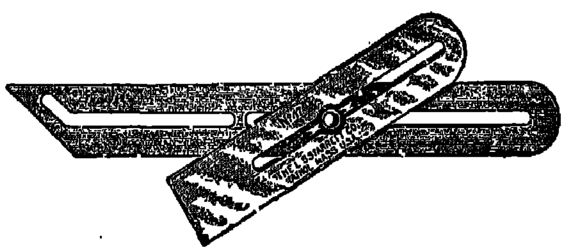
Use: The scriber is used for marking lines on metal, usually in conjunction with the straight-edge and square.



CENTRE PUNCH.

The Centre Punch is made of tool steel ground to a point at one end. The larger types, used for heavier work, have the point sharpened to an angle of 90 degrees, while the point on the lighter types is usually kept at an angle of 60 degrees.

Uses: The centre punch is used in conjunction with the hammer for clearly defining scribed lines, curves, points, etc., and for marking the centres of holes prior to drilling in order to give a lead to the drill.



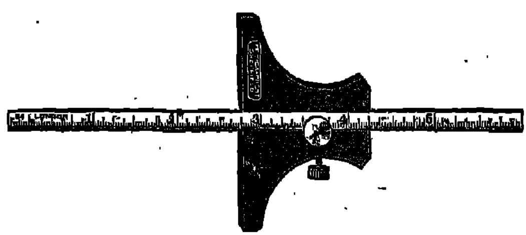
SLIDING BEVEL.

The Bevel is a tool similar in construction to a square, but with the blade either adjustable or fixed to the stock at an angle other than a right angle. It is used for testing and setting out lines, edges, etc., other than those at right angles.

CENTRE GAUGE.

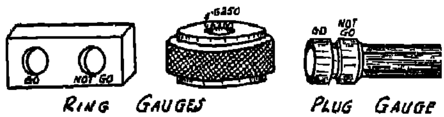
The Angle or Centre Gauge can be procured either external or internal, or with a combination of both. It is used for testing the angles of square and hexagonal nuts, also the angle of lathe centres and "V" threads, etc.

Depth Gauge: This tool consists of a beam or head through which passes a narrow graduated rule set at right angles to the base and adjusted by a thumb screw. It is used for measuring the depth of holes, recesses, etc., and distances from a surface.



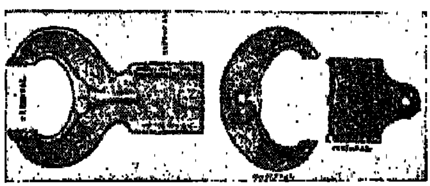
DEPTH GAUGE.

Plug Gauge is a type of limit gauge used to test or check the size of holes. Judging by the tightness or otherwise of the fit it indicates how much the work is under or over size. Plug gauges are guaranteed by the makers correct to 1/50,000 of an inch and can be obtained cylindrical, tapered or flat.



RING AND PLUG GAUGES.

Ring Gauge is the opposite to the plug gauge. It is used to test or check the external diameter of a shaft, pin or stud, etc. Plug and Ring gauges are made in any desired size from ¼-inch to 6 inches, and may be procured with "Go" and "Not Go" ends.



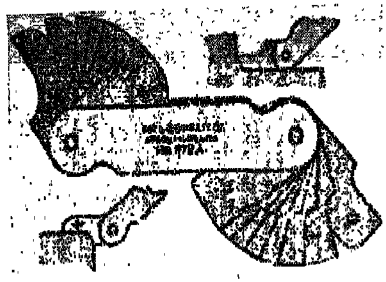
TYPES OF CALIPER GAUGES.

Snap or Caliper Gauges are rigid gauges made in definite sizes. They are used for gauging external dimensions and may be either single or double-ended with "Go" and "Not Go" ends. Sometimes they have one end external and the other internal. For general workshop use, caliper gauges are often preferred to the plug and ring forms, being lighter, cheaper and more convenient, also the latter can only be applied to the end of the work, whereas the former can be used at any point in its length.

FEELER GAUGE.

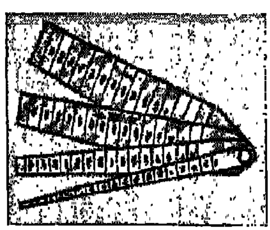
Feeler Gauge consists of a number of thin steel blades ranging in thickness from 1½ thousandths to 10 thousandths

of an inch. Blades may be used either singly or combined to give almost any desired size within the limits of the tool. These gauges are used for measuring small gaps or clearances.



RADIUS GAUGE.

Radius Gauge consists of a number of blades, each having a concave and a convex curve of the same radius on opposite sides of one end. It is used for testing the radii of fillets, curves, etc. Its construction is similar to that of a feeler gauge.



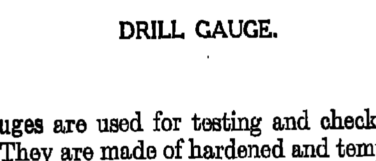
TAPER GAUGE.

Taper Gauge consists of several thin blades each tapering in width, the first commencing at $\frac{1}{16}$ inch and the width varying by $\frac{1}{64}$ of an inch to every $\frac{1}{4}$ inch of its length. They are graduated in $\frac{1}{4}$ inches and figured to read in fractions of an inch from $\frac{1}{16}$ inch to $1\frac{1}{16}$ inch. This gauge

is designed to measure the inside diameters of brass and steel tubing. It is convenient also for measuring the width of slots and holes and for setting calipers to sizes within its capacity.

SCREW PITCH GAUGE.

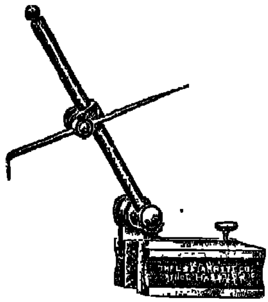
Screw Pitch Gauge has a number of thin blades which fold up into a handle. Each blade has two or more teeth, of the pitch corresponding to that stamped on the blade. By comparing it directly with a thread the exact pitch may be determined. The decimal following the pitch number on each blade is the double depth of the thread.



DRILL GAUGE.

Drill Gauges are used for testing and checking the sizes of drills. They are made of hardened and tempered bright, polished steel. The gauge illustrated above shows sizes from $\frac{1}{16}$ inch to $\frac{1}{2}$ inch varying by 64ths. Each size being designated by both common and decimal fractions.

The Scribing Block or **Surface Gauge** consists of a heavy base of cast-iron, hollowed underneath to present less bearing surface, an upright steel pillar attached to this base, and, on this pillar, a sleeve through which passes a cast steel scriber. This sleeve slides up or down the pillar



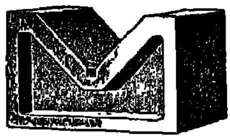
SURFACE GAUGE.

and can be fixed at any position by a thumbscrew or wing nut. The scriber is also adjustable, being moved either backwards or forwards or set at any angle. In some scribing blocks the pillar is fixed to the base by a

USING THE SURFACE GAUGE.

rocking bracket which allows it to be set at any angle to the base.

Uses: The scribing block is generally used with its base on a surface plate, "marking-off" table, or on the bed of a lathe, for the purpose of scribing lines and setting off points and centres on a piece of work. The bent or curved end of the scriber is useful for "feeling" surfaces for truth, or parallelism and testing for true running on the lathe.



"V" BLOCK.

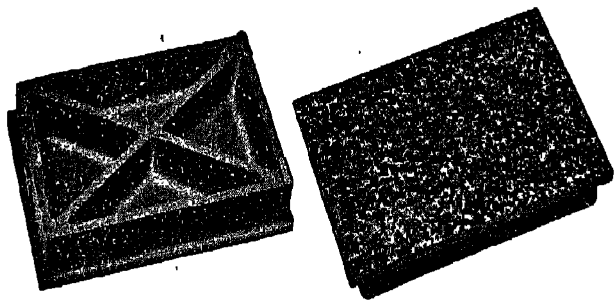
"**V**" **Blocks** are small blocks of cast-iron planed perfectly true and parallel, with either one or more "V"-shaped grooves cut into the faces. "V" blocks are usually made in pairs.

Uses: They are used for holding round bars whilst centering for turning, drilling, etc., in conjunction with *the scribing* block. They also act as a rest for circular work when drilling holes at right angles to the axis of the bar, the work being held in the blocks by means of clamps.

Surface Plate: This tool is a plane plate made of close-grained cast iron, the upper surface of which has been filed or planed and then scraped until it is perfectly true. The under side is ribbed to strengthen and support the plate and to counteract any tendency there may be for the surface to warp or twist.

A Marking-off Table is a larger variety of surface plate designed for the marking, testing, etc., of heavier or larger pieces of work.

Use: The surface plate is used for testing flat surfaces or edges when it is necessary that absolute truth be obtained. To test the truth of a surface a little "reddle" or "marking" (usually a mixture of red lead and oil) is rubbed on to the face of the plate and then the surface to be tested rubbed backwards and forwards over it; if the work is large, the surface plate may be rubbed over the work.



SURFACE PLATE.

The high parts of the work will be revealed by having smears of reddle on them; these should then be filed or scraped down and the work again tested on the plate. These operations are repeated until the whole surface of the work is smeared evenly with reddle, proving that it is in contact with the plate and therefore true.

Care of the Surface Plate: Owing to the care, time and labour expended to reach this high degree of truth on the face of the surface plate, it is a very expensive tool. Care must, therefore, be exercised to see that the surface is not marred or damaged in any way. When using it, wipe any dust or grit from the surface of both the plate and the work, otherwise the face may be scratched. When not in use it should be kept oiled to prevent rusting, as this would impair its accuracy and it should be covered with a wooden box for protection.

Questions :

1. Name the principal "marking-off," measuring and testing tools.
2. Why are these tools so classified ?
3. What is meant by the term "marking-off" ?
4. What is meant by "reddle" ?
5. How would you prepare the copper-sulphate solution used for coating surfaces ?

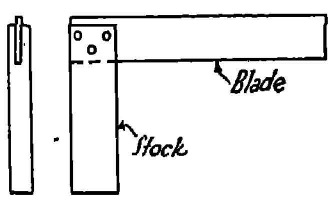
THE ENGINEER'S SQUARE.

There are many different types of squares used by the engineer in everyday practice, some of which are as follows :—

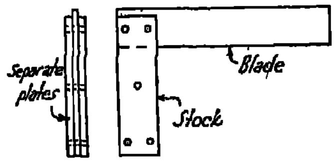
(a) The Try Square.
(b) The Flat Square.
(c) The Combination Square.
(d) The Centre Square.
(e) The Box Square.

The type most frequently used, however, is the Try Square.

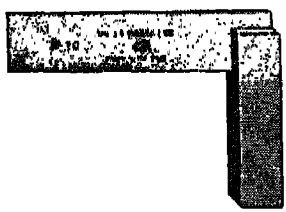
(a) **The Try-Square :** This consists of two parts, the stock and the blade, the former usually being made of mild steel and the latter of tool (spring) steel. There are three main methods of making this type of square.



1. The stock is shaped to size and a slot cut in one end, the blade is prepared and, after being inserted into the slot cut in the stock, is riveted into position at right angles to the stock. The main weakness of this type is the danger of movement at the rivets, causing it to get out of truth.



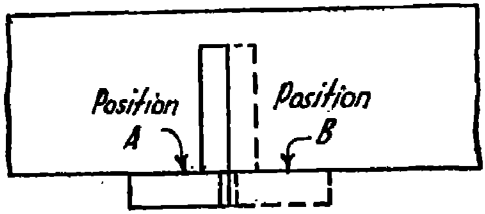
2. This method gives what is known as a "built-up" square, consisting of three pieces: one angle piece, which forms both the blade and the middle of the stock, and two face pieces, riveted to the angle piece to form or "build up" the complete stock. This type is much more reliable than the former, but costs a little more to manufacture.



3. In this method, the square is forged from solid cast steel and machined to give extreme accuracy. Owing to the method of manufacture, this type is much more expensive than types 1 and 2.

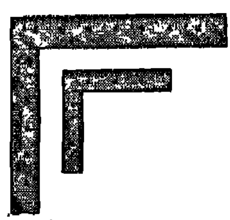
Use of the Try-Square: It is used for testing external and internal right angles, for setting out angles of ninety degrees, usually from a finished edge, and for accurately setting up work for drilling, etc., on the various machines in the workshop.

This square is specified by the length of the blade, the length being measured from the inside of the stock, and can be obtained with the blade either plain or graduated into inches and fractions of an inch.



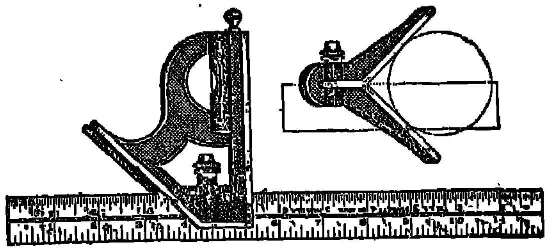
TESTING A SQUARE.

Testing a Try-Square: To test a try-square, first test the edges of both stock and blade to find out if they are true and parallel. It is next necessary to obtain a plate with a perfectly flat surface and a straight edge. The stock of the square is then placed against the straight edge, with the blade resting on the flat surface, and a line drawn with a scriber along the edge of the blade, leaving an impression on the flat surface. The square is then reversed, i.e., turned over, and if the edge of the blade now coincides with the scribed line the square is true. If, however, the edge and the line do not coincide, the square is inaccurate to the extent of half the variation of the angle the reversed square position makes with the original scribed line.



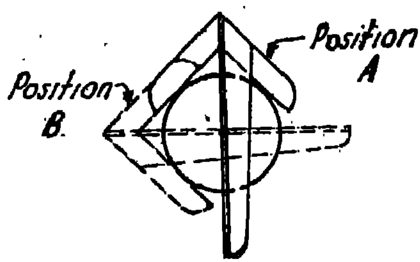
FLAT SQUARE.

(b) **The Flat Square** is made of steel and is usually graduated for its full length on both sides. It is used mainly for working on flat surfaces, such as sheet metals and for places where the stock of a try-square would bo inconvenient.



COMBINATION SQUARE.

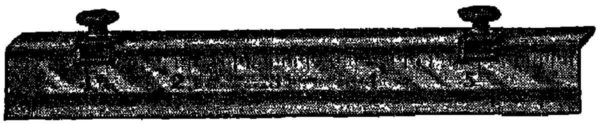
(c) **The Combination Square** is a very useful tool which, with careful use, will retain its accuracy. It is used for functions similar to those of a try-square, for making and testing angles of 45°, also for use as a depth gauge and spirit-level.



USING THE CENTRE SQUARE.

(d) **The Centre Square:** The common type has the inside of the stock in the form of a right angle which is bisected by the edge of the blade. It is used for finding the centres of round bars or discs; to do this, first place the disc to be centred in the angle or fork, draw a line along the blade, then move the square through a quarter

circle and again draw a line along the blade, intersecting the former line. The point of intersection of these two lines marks the centre.



BOX SQUARE OR KEY SEAT RULE.

(e) **The Box Square, or Key-Seat Rule,** is right angular in shape and is graduated on both edges. With the aid of this tool, lines, which are parallel to the axis, may be drawn upon a cylindrical surface.

SUMMARY.

Classification: "Marking-off" and measuring tool.

Types: There are many types of engineers' squares, *e.g.*, the Try-Square, Flat Square, Combination Square and Centre Square, the one most frequently used being the Try-Square.

Parts: The parts of the Try-Square are :—

(a) The Blade.

(b) The Stock.

The blade is made of spring steel and the stock of mild steel. There are three methods of making a try-square, viz. :—

1. The stock and the blade are shaped to size, the blade is inserted into a slot cut in the stock and then riveted at right angles to it.

2. The "built-up" square is formed by riveting face pieces to an angle piece which forms the middle portion of the stock as well as the blade.

3. In this method the try-square is forged from the solid and is extremely accurate.

Try-squares are specified by the length of the blade, measured from the inside of the stock.

Uses: They are used for setting out and testing right angles and for accurately setting up work on the various machines in the workshop.

Questions:

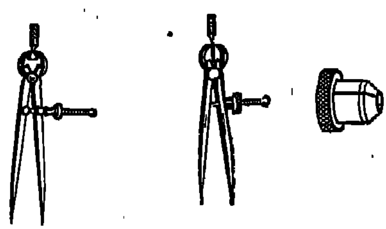
1. Name four different types of squares.
2. Name the metals used in their manufacture.
3. How are squares specified?
4. How would you test a try-square?
5. State briefly the uses of the try-square.

DIVIDERS.

Dividers are made in several forms, but the following two are most commonly used :—

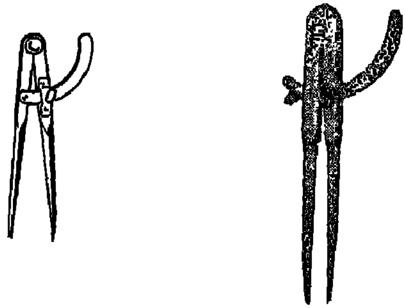
1. Spring Dividers.
2. Wing Compasses.

1. **The Spring Dividers :** These are made of tool steel and can be obtained in lengths varying from 2 up to 8 or 10 inches. The legs are ground to shape, being pointed at one end and fitted with a pivot and spring at the other. This spring fits into two small grooves and tends, by its inward pressure, to force the points apart. Adjustments are made by a long screw-threaded arm fitted with a nut. Some spring dividers have a "quick" nut, i.e., the nut is in two sections which, when together, grip the thread, but, when loose, open out, permitting it to be slid or moved freely along the arm, thus allowing quick and easy adjustment of the dividers.



SPRING DIVIDERS.

Spring dividers, by reason of their construction, are more accurate than other types and so are preferred for finer and more accurate work, for, although the making of alterations and adjustments might be a little slower, their greater accuracy more than compensates for the time lost.



WING COMPASSES.

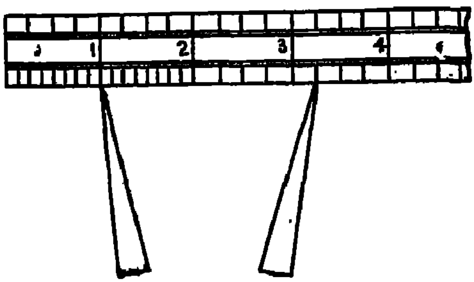
2. **The Wing Compasses** are heavier in design than the spring dividers. They are made of high-grade tool steel, with hardened and tempered points, and can be obtained in lengths ranging from 6 to 12 inches. They comprise two legs, fixed by a pivot or joint at the top, and a curved arm or "wing" which is attached to one leg and which passes through a slot cut in the other. To adjust these compasses the loose leg is moved, with the fingers, along the quadrant or curved arm. Some types are fitted with a small spring and nut device on the fixed leg, allowing for finer adjustment.

The wing compasses are not considered to be as accurate as spring dividers, on account of their adjusting device; they are more likely to shift slightly if dropped or bumped; therefore, they are used on work of a heavier and less accurate nature.

Uses of the Dividers: They are used for marking out and subdividing curves and circles, dividing, spacing out distances, and for transferring measurements.

Using the Dividers: When setting the dividers to a rule, the point of one leg should be placed on an inch mark and the setting made therefrom. The points should always be kept finely sharpened, by means of an oilstone,

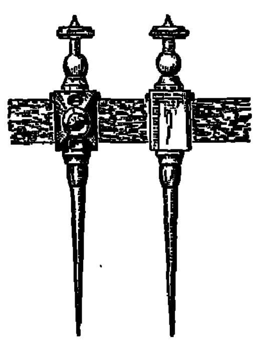
and care should be exercised to prevent these somewhat brittle points from becoming damaged or injured in any



SETTING THE DIVIDERS.

way. The adjusting screw and nut should be kept well lubricated and working freely, so that the tool may be used to its finest limits.

Trammels : Mention might here be made of the means used by the engineer or metal worker for scribing or spacing out distances outside the scope or range of his dividers. These are known as trammels, and consist



THE TRAMMELS.

of two separate pointed legs, with rectangular slots, through which a metal or wooden rod may be passed.

The trammels are held in position by adjusting screws at the top. The scope of this tool depends wholly upon the length of the rod.

Questions :

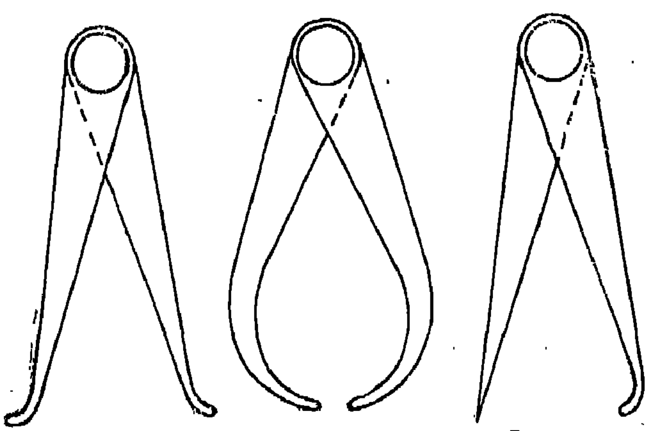
1. Name the parts of the spring dividers.
2. Why are the spring dividers usually employed for work of a finer nature ?
3. How would you set the dividers from a rule ?
4. How should the dividers points be sharpened ?
5. State the uses of the dividers.

CALIPERS.

Calipers are used for the measurement and transfer of sizes. They should be made of high-grade tool steel with well-proportioned legs, preferably tempered, and should have a carefully fitted joint with a uniform amount of friction at all positions of the legs, thus giving a smooth, steady motion when setting.

Although there are many variations of each, the three most important types of calipers are, viz. :—

1. The Outside Calipers.
2. The Inside Calipers.
3. The Jenny or Odd-leg Calipers.



TYPES OF CALIPERS.

These particular types are referred to as transfer calipers to distinguish them from the recording types, such as the Vernier Calipers and the Micrometer. **Transfer**

Calipers take three general forms, the *Firm joint*, *Lock joint* and the *Spring Calipers*, the two latter often being referred to as adjustable calipers.

Uses :

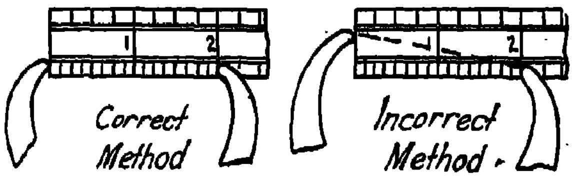
1. **The Outside Calipers** are used for :—
   (a) Measuring and testing the outside diameters of pipes, shafts, wheels and other similar objects.
   (b) Measuring and testing the thickness of metal plate and blocks.
   (c) Testing outside edges or surfaces for parallelism.
   (d) Transferring external measurements and sizes from one piece of work to another.

2. **The Inside Calipers** are used for :—
   (a) Measuring and testing the inside diameters of pipes, holes, etc., and the width of slots.
   (b) Testing inside surfaces for parallelism.
   (c) Transferring internal measurements from one piece of work to another.

3. **The Jenny** or **Odd-Leg Calipers**, often referred to as hermaphrodite calipers, have one leg pointed as in a divider, and the other curved in a manner similar to the inside calipers. This type is used for :—
   (a) Scribing lines parallel to an existing edge.
   (b) Locating the centre on the ends of round bars, shafts, etc.

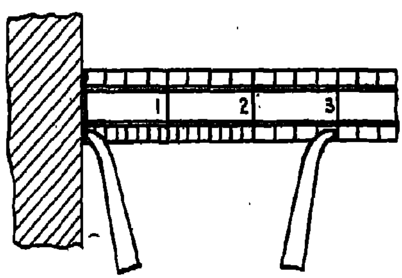
Using the Calipers : The skilful use of calipers depends entirely upon the good judgment and delicate touch of the operator, accuracy depending largely upon the sense of touch in the finger tips. As contact between the points of the calipers and the work must be recognised

without pressure, the tool must therefore be grasped lightly, as harsh handling considerably diminishes this sense of touch. Ability to use and handle these tools correctly is attained only after much practice.



SETTING THE OUTSIDE CALIPERS.

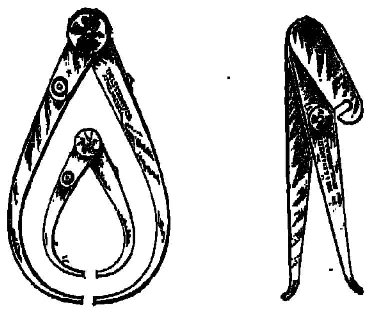
Setting the Calipers: Calipers are usually adjusted by finger pressure or by gently tapping. When setting the outside calipers, they should be held in the right hand and the rule held vertically in the left, with the end of the little finger against the end of the rule to steady the lower leg of the calipers. The measurement is then made from the end of the rule.



SETTING THE INSIDE CALIPERS.

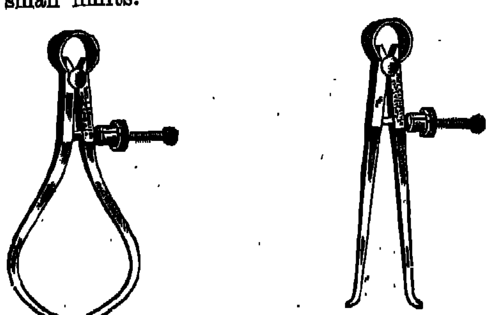
When setting or reading the inside calipers, place both the rule and one leg of the calipers against some solid body to ensure accuracy. Care should be exercised, however, to see that both points of the tool are held either at the edge of the rule or at the same distance from it,

otherwise the setting will not be strictly accurate. It is not a good practice to set both points to lines on the rule, as the probability of error is much greater than when the measurement is taken from the end, in the manner described above.



LOCK JOINT CALIPERS.

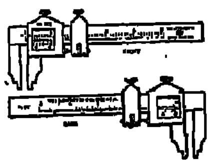
The Lock-Joint Callipers are similar in construction to the ordinary firm joint, with the addition of a small arm and thumb-screw device, whereby the legs may be locked in position after being set. Some types are also fitted with a screw adjusting device which allows adjustment within small limits.



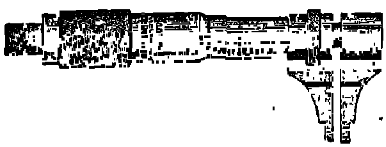
SPRING CALIPERS.

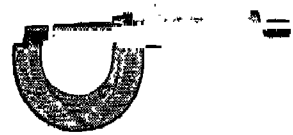
The Spring Calipers are similar in design to spring dividers, but with caliper legs, instead of the straight divider type.

Vernier Calipers and **Micrometers** are used by the engineer for measuring with great accuracy. Some micrometers are designed to measure to an accuracy of one ten-thousandth part of an inch.



VERNIER CALIPERS.





MICROMETER (INSIDE). MICROMETER (OUTSIDE).

SUMMARY.

Classification : " Marking-off " and measuring tool.

Types : There are three main types of Calipers in common use, viz. :—

1. Inside Calipers.
2. Outside Calipers.
3. Jenny or Odd-leg Calipers.

Parts : Legs, washers and pivot. The legs are made of tool steel and the washers and rivet of mild steel.

Uses :

1. *The Outside Calipers* are used for obtaining the outside diameter of pipes, shafts, etc., measuring the thickness of metal plates, testing outside faces for parallelism and for transferring measurements.

2. *The Inside Calipers* are used for obtaining the inside diameter of pipes, holes, etc., width of slots, testing inside faces for parallelism and for transferring measurements.

3. *The Jenny Calipers* are used for scribing lines parallel to an existing edge and for finding the centres of round bars or discs.

When using the calipers, grasp them lightly, as accuracy depends largely upon the sense of touch in the fingertips. The calipers are adjusted by finger pressure or by gentle tapping.

Questions :

1. Name three types of transfer calipers.
2. State the uses of one type.
3. Describe the method of setting calipers.
4. What is the advantage of the lock-joint calipers ?
5. How are firm-joint calipers adjusted ?

PROPERTIES OF METALS.

All metals possess certain properties and characteristics which make them valuable, or otherwise, to the engineer or sheet metal worker. One metal, for example, might be suitable for a certain purpose, whereas another would be quite useless, or even dangerous, were an attempt made to make it do the same work. The engineer must therefore be guided, in his choice, by the characteristics and properties possessed by the various metals.

The properties and characteristics of the metals in general commercial use may be set out as follows :—

Colour: While not a very important property for general engineering purposes, colour is, nevertheless, one that has to be considered when using metals for ornamentation. The following list shows the colour of the common metals :—

METAL	COLOUR	METAL	COLOUR
Aluminium ...	Silver-Grey	Platinum ...	Silver-Grey
Copper	Reddish-Brown	Steel ...	Grey
Gold	Yellow	Silver ...	Silver-White
Iron	Grey	Tin	Silver-White
Lead	Bluish-Grey	Zinc	Greyish-White

Weight: All metals have weight. This may be defined as the force with which the earth attracts a substance (i.e., the pull of gravity). The "Specific Gravity" of a metal is the ratio between the masses of equal volumes of that metal and water, the water being at a temperature of 60° F.

The following table gives the approximate weight per cubic inch and the specific gravity of the common metals:—

METAL	Approx. Wt. of 1 cubic in. (lbs.)	Specific Gravity	METAL	Approx. Wt. of 1 cubic in. (lbs.)	Specific Gravity
Platinum	0.78	21.5	Nickel	0.31	8.7
Gold	0.69	19.2	Steel	0.28	7.8
Mercury	0.49	13.6	Wrought Iron	0.28	7.7
Lead	0.41	11.4	Tin...	0.26	7.4
Bismuth	0.35	9.8	Cast Iron ...	0.26	7.2
Copper	0.32	8.9	Zinc	0.26	7.1
Brass	0.31	8.2	Antimony ...	0.24	6.7

Tenacity: This is the power of a metal to resist the effort of stretching or pulling apart; it depends upon the force of cohesion between the particles. This is one of the most important properties, and is possessed to a greater or lesser extent, by all metals, with the exception of mercury. Upon it depends the structural value of such metals as mild and cast steel.

The following table gives the approximate tensile strength of the common metals and alloys:—

METAL	Average TENSILE STRESS Tons per sq. inch	METAL	Average TENSILE STRESS Tons per sq. inch
Cast Steel ...	45	Gunmetal ...	14
Mild Steel ...	40	Aluminium ...	10
Wrought Iron	25	Cast Iron ...	10
Copper	20	Gold	8
Silver	17	Zinc	2.5
Brass	15	Tin	2.2
Malleable C. I.	14	Lead	1.0

Shearing: The shearing strength of a metal is its ability to resist a force which, when applied at right angles to the axis would cause the two parts to separate.

Malleability: This is the ability of a metal to be extended, i.e., thinned out without fracture, by hammering, rolling or pressing. It is determined by comparing the thinnest sheets obtainable from the various metals. Metals generally become more malleable when heated. The following table shows the relative abilities, in descending order, of the common metals, to be thinned out, when subjected to hammering and rolling :—

HAMMERING		ROLLING	
1. Lead	5. Silver	1. Gold	5. Lead
2. Tin	6. Copper	2. Silver	6. Zinc
3. Gold	7. Platinum	3. Copper	7. Platinum
4. Zinc	8. Iron	4. Tin	8. Iron

Ductility: This property is a combination of tenacity and malleability. It is the ability of a metal to be extended lengthwise, by drawing or stretching, and to remain extended. Only ductile metals can be drawn into wire. Wire-drawing is done in a cold state as the ductility of most metals is greater when cold than hot.

The following table shows the relative ductility of metals when subjected to wire-drawing :—

1. Platinum	4. Copper	7. Tin
2. Silver	5. Gold	8. Lead
3. Iron	6. Zinc	

Hardness: This is the power of a metal to resist penetration or abrasion by scratching or cutting. The term "Glass hard," when referring to a piece of steel, means that the surface is so hard that a file will not make any impression upon it.

To find the relative hardness of two metals one should be rubbed against the other, when the harder one will scratch the softer. A useful workshop method is to indent both pieces of metal with a centre punch and hammer, using the same weight of blow on each, the piece with the deeper indentation being the softer. Somewhat similar to this latter method is that used by scientists for measuring the hardness of metals, this is termed the "Brinell" method, after its originator. It consists of placing a hard steel ball on the metal to be tested and forcing it into the surface, under a known pressure, then measuring the depth of the indentation thus made. The table below gives the relative hardness, in descending order, of the common metals :—

1. Cast Steel	5. Brass	9. Zinc
2. Mild Steel	6. Copper	10. Aluminium
3. Cast Iron	7. Silver	11. Tin
4. Wrought Iron	8. Gold	12. Lead

Conductivity : This is the ability of a metal to conduct heat or electricity. Most metals are good conductors, but this property is considerably increased in those that have been drawn or rolled rather than cast. The table below gives the ability, in order, of the common metals in this respect :—

CONDUCTIVITY (for Heat)		CONDUCTIVITY (for Electricity)	
1. Silver	6. Tin	1. Silver	6. Iron
2. Copper	7. Iron	2. Copper	7. Platinum
3. Gold	8. Platinum	3. Gold	8. Tin
4. Aluminium	9. Lead	4. Aluminium	9. Lead
5. Zinc		5. Zinc	

Fusibility: While all metals except mercury are solid under atmospheric conditions, all can be changed to a fluid state when heated to a sufficiently high temperature. Advantage is taken of this property to make alloys, to produce castings of desired shapes and to unite metals by the processes of brazing, welding and soldering. The table set out below gives the approximate melting points of the common metals, both Centigrade and Fahrenheit :—

METAL	MELTING POINT		METAL	MELTING POINT	
	Degs. Cent.	Degs. Fah.		Degs. Cent.	Degs. Fah.
Platinum	1775	3227	Aluminium	654	1209
Wrought Iron	1593	2900	Antimony	450	842
Steel	1371	2500	Zinc	360	700
Cast Iron	1148	2100	Lead	326	620
Copper	1093	2000	Bismuth	252	487
Silver	960	1760	Tin	246	475

Compression: The ability of a metal to resist a crushing force is called its compressive strength. Metals with this property are suitable for columns to carry loads. The following table gives the compressive strength of some few of the more common metals :—

RESISTANCE TO COMPRESSION.

METAL	RESISTANCE	METAL	RESISTANCE
1. Cast Iron	45 tons per sq. in.	3. Wrought Iron	20 tons per sq. in.
2. Mild Steel	30 tons per sq. in.	4. Brass	4 tons per sq. in.

Expansion: This is the amount a metal increases in length under the influence of heat. The co-efficient of expansion is the amount every unit of length expands for every degree rise in the temperature. A comparison of expansions of the common metals between 320° F. and 212° F. gives the following results :—

METAL	EXPANSION	METAL	EXPANSION
Zinc	1 part in 322	Brass ...	1 part in 584
Lead	1 „ „ 349	Wrought Iron ...	1 „ „ 846
Block Tin ...	1 „ „ 403	Cast Iron ...	1 „ „ 901
Copper	1 „ „ 581		

Elasticity: This is the ability of a metal to return to its original form and dimensions after the removal of the load. If stretched beyond its elastic limit a metal or alloy will take a permanent set and not return to its original form. Elasticity is measured :—

1. As regards range—by the "elastic limit" stress.
2. As regards degree—by the "modulus of elasticity."

Plasticity is the reverse of elasticity. It is the ability of a metal to retain permanently the shape it assumed under load, when the load is removed. Plasticity is somewhat similar to ductility. It is very useful in the manufacture of articles that are shaped by pressing and stamping such as kitchen utensils, coins, etc. It is also a very necessary property in the production of articles made from synthetic resins and other plastic compounds.

Toughness is the ability of a metal to resist fracture when being bent backwards and forwards or twisted.

Brittleness is the opposite to toughness and is the tendency of a metal to break upon receiving a blow or being bent.

Weldability is that property of metals which renders them capable of being joined by hammering or pressing at welding heat.

SUMMARY.

All metals possess certain properties which make them of value to the engineer. He is able to use them as a guide when choosing metals for certain purposes. The most important of these properties are :—

Colour, while not a particularly important property, it is of value to the craftsman who uses metals for ornamentation.

Weight: All metals have weight. This may be defined as the force with which a substance is attracted by the earth (i.e., the pull of gravity).

Tenacity is the ability of a metal to resist the effort of stretching or pulling apart. Its possession makes metals valuable for structural purposes.

Malleability is the ability of a metal to be thinned out, without fracture, by hammering and rolling.

Ductility is a combination of tenacity and malleability. It is the ability of a metal to be extended lengthwise by drawing or stretching, *e.g.*, wire-drawing.

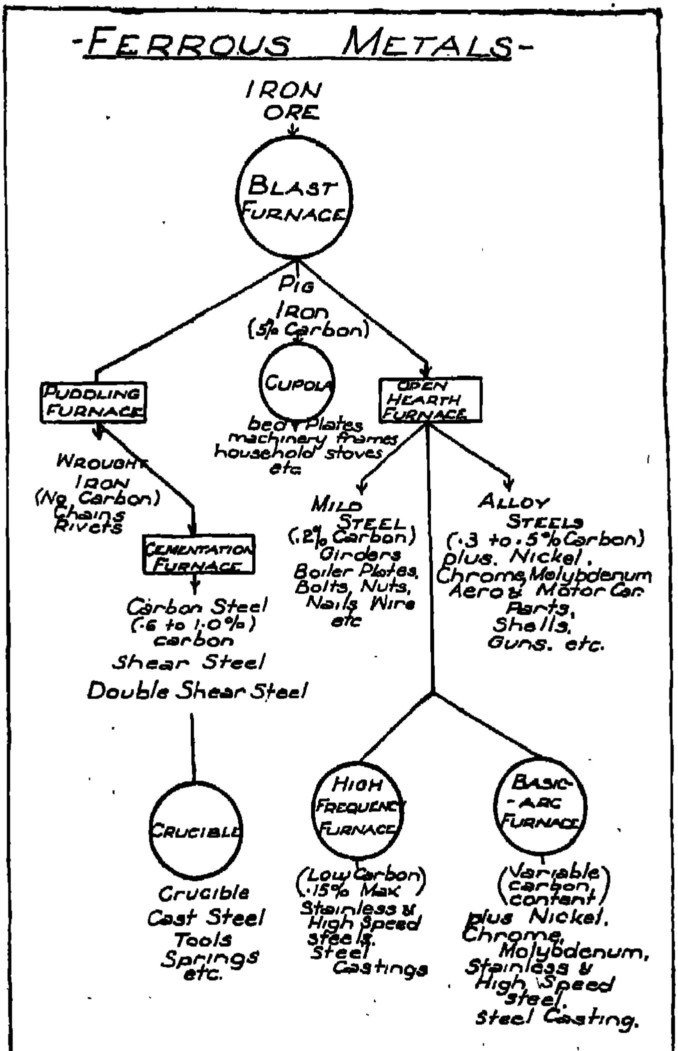
Hardness is the power of a metal to resist penetration or abrasion by scratching or cutting.

Conductivity is the ability of a metal to conduct electricity and heat. This is increased in metals that have been drawn or rolled.

Fusibility is the property of a metal which allows it to change from a solid state to a liquid or molten state on the application of heat.

Questions:

1. How does a knowledge of the properties of metals assist the engineer'?
2. Which metals are the best conductors of heat and electricity?
3. What use is made of the ductility of metals?
4. What advantage is taken of the fusible property of metals?
5. How would you test a piece of metal for hardness?


-FERROUS METALS-
IRON ORE
BLAST FURNACE
PIG IRON (5% Carbon)
PUDDLING FURNACE
CUPOLA
bed Plates machinery frames household stoves etc
OPEN HEARTH FURNACE
WROUGHT IRON (No Carbon) Chains Rivets
CEMENTATION FURNACE
Carbon Steel (·6 to 1·0%) carbon
Shear Steel
Double Shear Steel
MILD STEEL (.2% Carbon) Girders Boiler Plates, Bolts, Nuts, Nails Wire etc
ALLOY STEELS (·3 to ·5% Carbon) plus. Nickel. Chrome, Molybdenum Aero & Motor Car Parts, Shells, Guns. etc.
CRUCIBLE
Crucible Cast Steel Tools Springs etc.
HIGH FREQUENCY FURNACE
(Low Carbon) ·15% Max
Stainless & High Speed steels. Steel Castings
BASIC-ARC FURNACE
(Variable carbon content)
plus Nickel, Chrome, Molybdenum, Stainless & High Speed steel. Steel Casting.

FERROUS METALS.

Ferrous metals are those composed chiefly of iron (*Ferri-iron*). They were known, in some forms, long before the Steel Age began, the first iron on record being placed in an Egyptian pyramid more than 5,000 years ago; the Romans also were manufacturers and users of these metals. A mediaeval furnace could only produce from 100 to 150 tons of iron a year, whereas a modern blast furnace produces up to 600 tons a day.

Ferrous metals are manufactured in four main forms, viz. :—

1. Pig or Cast-iron.
2. Wrought-iron.
3. Mild Steel.
4. Tool or Cast Steel.

1. **Pig Iron**: When thought is given to the vast importance in the engineering world of the last three of the abovenamed metals, and it is realized also that all are derived from the first, i.e., Pig Iron, it must be admitted that the manufacture of this metal plays a most important part in industrial and metallurgical spheres.

This metal is produced from iron ore by the process of smelting in the **Blast furnace.** Prior to smelting, the iron ore undergoes two main processes :—

1. *Washing* to remove impurities, such as clay, sand and rock.

2. *Crushing* to reduce the ore to suitable sizes for smelting.

The iron ore is introduced into the furnace together with coke, which acts as a fuel, and limestone which, acting as a flux, melts and absorbs the coke residue. The limestone also combines with any impurities from the ore, rendering them sufficiently fluid to be removed later, in the form of slag, from the surface of the molten iron.

A hundred years ago a blast furnace consisted of a stack and a blower, but to-day it consists of an enormous steel shell, often 100 feet high, lined with fire-resisting brick. The iron ore, flux and fuel are put into the furnace through the opening in the top. The combustion of the fuel is intensified, and the melting of the ore hastened, by the introduction of a blast of hot air into the furnace through tuyeres (pronounced twee-ers) near the base. When the ore is reduced to a molten state it collects in the hearth, with the slag floating on top. This latter is drawn off through the slag notch. When the level of the molten iron rises to that of the slag notch the furnace is tapped and the iron drawn off into ladles. The tapped metal is cast into small moulds called pigs, unless it is to be used immediately in the manufacture of steel, in which case it is taken to a huge vat, called a mixer, where it is kept in a molten state until required.

The slag and iron are tapped from the furnace several times a day, while charges, consisting of iron ore, limestone and coke, are constantly added to the interior of the furnace. A furnace operates continuously until it is shut down for repairs or because there is no further demand for its product. (See diagram, page 138A.)

Pig Iron is usually classified into three types—White, Grey and Mottled.

White Pig Iron is greyish-white in colour with a fine (close) grain. It has a melting point of about 1300°C., is extremely hard and brittle and is the metal used in the production of malleable and large castings and for converting into wrought iron.

Grey Pig Iron is dark grey in colour with a large (open) grain, it is softer, less brittle and somewhat less fusible than white pig iron but in a molten state is more fluid than the latter metal. Grey pig iron has a melting point of about 1400°C. and expands slightly just before solidifying, which characteristic makes it very suitable for fine castings as it enables it to take a clean, sharp impression

when cast into a mould. This is the variety of pig iron most frequently used in the production of ordinary castings and for steel making.

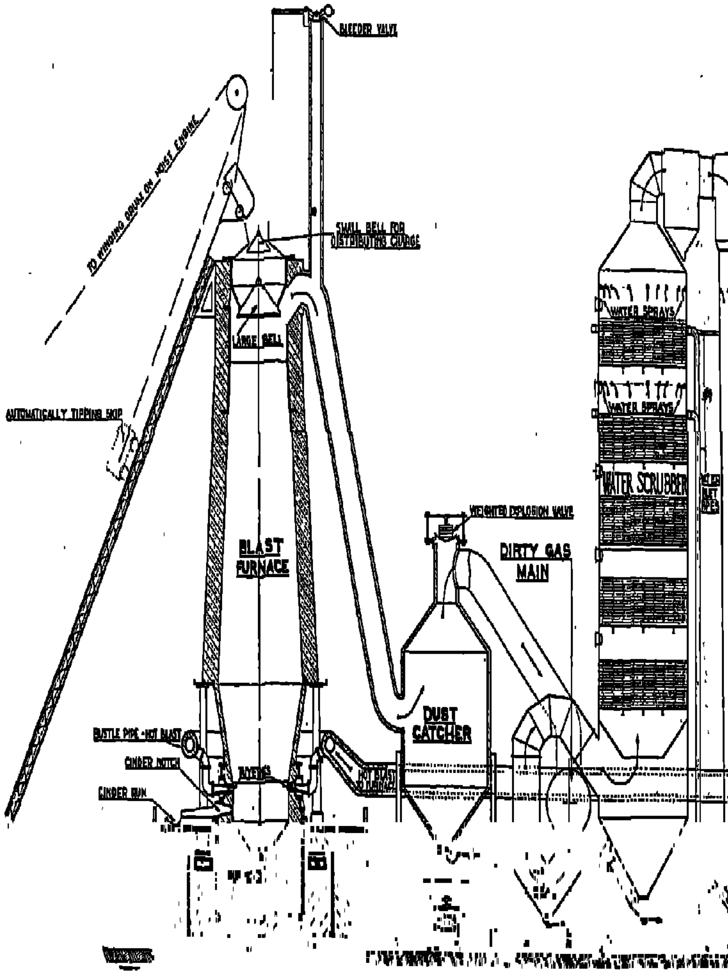
COMPOSITION	PIG IRON	
	WHITE	GREY
	per cent.	per cent.
Graphitic Carbon	—	3.30
Combined Carbon ...	3.20	0.20
Silicon	0.64	3.50
Phosphorus	1.32	0.98
Sulphur	0.20	0.02
Manganese	0.60	1.58
Iron	94.04	90.42
	100.00	100.00

Mottled Pig Iron, as the name implies, is mottled in appearance, being a combination of the former two.

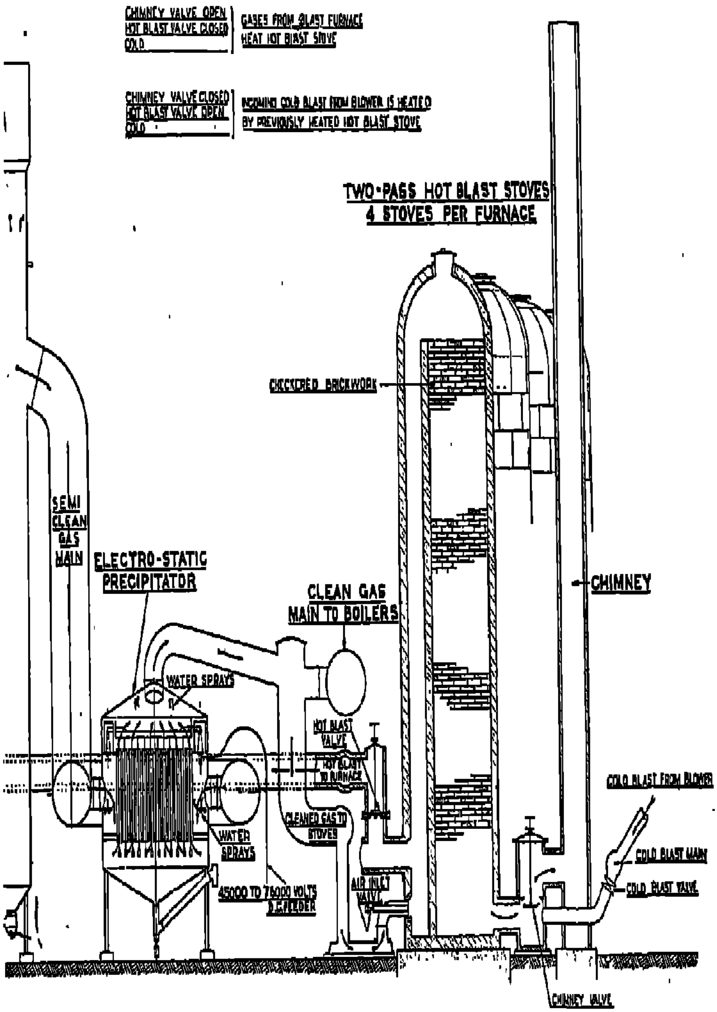
Pig iron has a coarse granular structure and contains from 2% to 4% carbon. It is neither ductile nor tenacious, but is hard, brittle and very strong in compression.

Cast Iron is produced in the "cupola" by remelting pig iron with scrap cast iron. It is then poured into sand moulds and allowed to cool slowly. Cast iron can be cast into any desired shape, but cannot be forged or fire welded. It is used in the manufacture of machinery bedplates and frames, cylinders, pistons, piston rings, vices, stoves, etc.

Malleable Cast-iron: When machinery parts of intricate design are required for work where cast-iron is too brittle, malleable castings are used. These castings are first



DIAGRAMMATIC ARRANGEMENT O



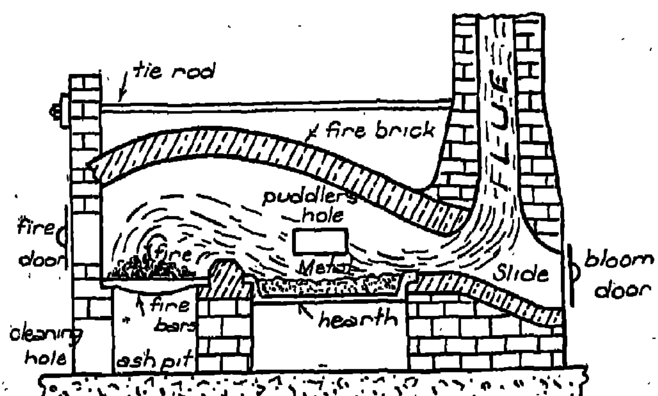
F BLAST FURNACE SYSTEM.

[See descriptive matter page 137.

produced from hard "white" iron containing about 3.5% carbon and are annealed by placing in iron boxes with powdered red haematite (oxide of iron) and baking at a high temperature, for a sufficient length of time, to allow a portion of the carbon in the iron to unite with the oxygen in the oxide. This heat treatment burns out some of the carbon from the castings and introduces a degree of malleability and toughness. Malleable castings will not stand forging but they have a higher tensile strength and are more ductile than before treatment.

2. **Wrought-iron** is manufactured from pig iron by extracting the carbon. This is done in a **Puddling furnace**, and the process adopted is as follows :—A heavy charge of pig iron is introduced into the furnace on to a bed of red haematite (oxide of iron) or fettling, the latter consisting of haematite, hammer slag, scale, etc., and other such substances rich in oxygen ; this oxygen, combining with the carbon in the pig iron, causes it to be burnt out, with the result that the molten metal is reduced to a doughy or pasty mass.

After removing as much slag as possible from the surface, the puddler works the iron into balls or blooms, weighing from 60 to 80 pounds. A bloom is then brought



-PUDDLING FURNACE-

to a welding heat, withdrawn from the furnace and hammered to squeeze out any remaining slag and to weld the iron into a solid mass, after which treatment it is rolled down into bars by passing between grooved rollers.

After this treatment the iron is known as *Puddled Bar*, but is still not sufficiently homogeneous to have any commercial value, so it is cut into lengths, faggoted (i.e., the lengths are tied together with wrought-iron wire), reheated to a welding heat and again hammered, giving us *Common Iron* or *Merchant Bar*. This process of heating and rolling is carried out four times in all, giving, in turn, *Common Iron, Best Iron, Best Best Iron,* and *Treble Best Iron*. Each rolling improves the metal by gradually eliminating the slag and increasing the uniformity of the structure. Experience has taught that further working of the metal, beyond the point of Treble Best Iron, causes a gradual deterioration and weakening of the structure.

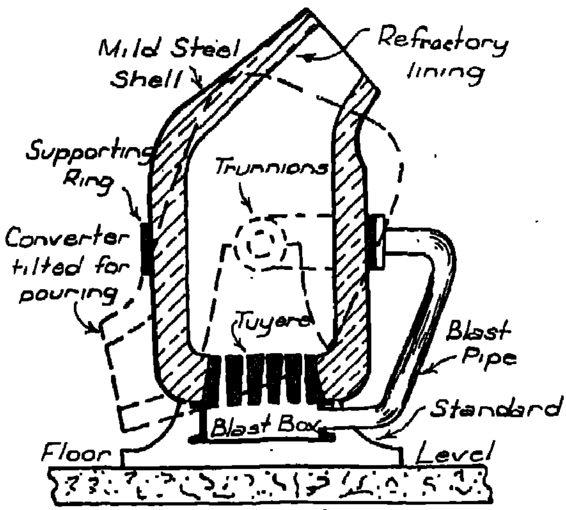
Wrought-iron is reddish-grey in colour, with a fine fibrous structure, and is tough, malleable and ductile. It has been superseded almost entirely by mild steel, but on account of its good welding properties it is used largely for the manufacture of chains and waterpipes.

3. **Mild Steel** is the most widely used of the ferrous metals. It is manufactured from pig iron either by the " Bessemer Converter " or " Open Hearth " process.

The process is one of burning out the carbon and silicon from the pig iron and afterwards adding a known percentage of carbon in the form of spiegeleisen, a Swedish ore rich in carbon, or ferro-manganese.

The Bessemer Process: *The Bessemer Converter* is a huge pear-shaped vessel made of steel plates and lined with heat-resisting bricks. It is open at the top and may be tilted. The base is perforated so that a powerful blast of air may be forced through the mass of molten iron. During the passage of this air through the iron the oxygen combines with the carbon and burns it out.

When this stage is reached the spiegeleisen (ferro-manganese) is added to furnish the metal with the percentage of carbon, manganese, etc., required to convert



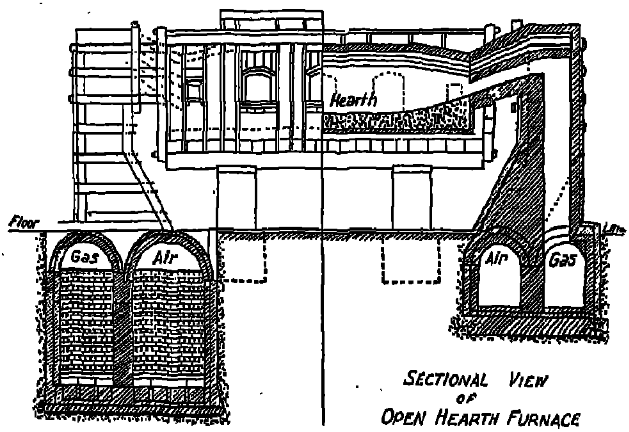
·BESSEMER CONVERTER-

it into steel. The Bessemer process takes from 15 to 20 minutes to convert iron into steel, a large converter being capable of producing 2,800 tons a day.

The Open Hearth Process: This process does not produce steel as quickly as the Bessemer process, but has the advantage of being much more under control, so that the metal can be tested frequently in order to ascertain the exact percentage of carbon and grade of steel.

In the Open Hearth process the removal of carbon is brought about by surface oxidization. This is caused by passing an intensely hot flame over the surface of the molten metal. To help this, the metal is contained in a shallow hearth, which allows a very large area to be exposed to the action of the flame.

Some furnaces are charged with pig iron in a solid state, but, where the process is continuous, molten iron is poured into the furnace from mixers, and to assist the action of the flame, quantities of steel scrap and iron ore rich in oxygen are introduced. Limestone is also added; it floats on the surface of the molten metal as slag and absorbs all the impurities. When the carbon has been entirely removed from the iron the mass is said to be decarbonized. A quantity of ferro-manganese is



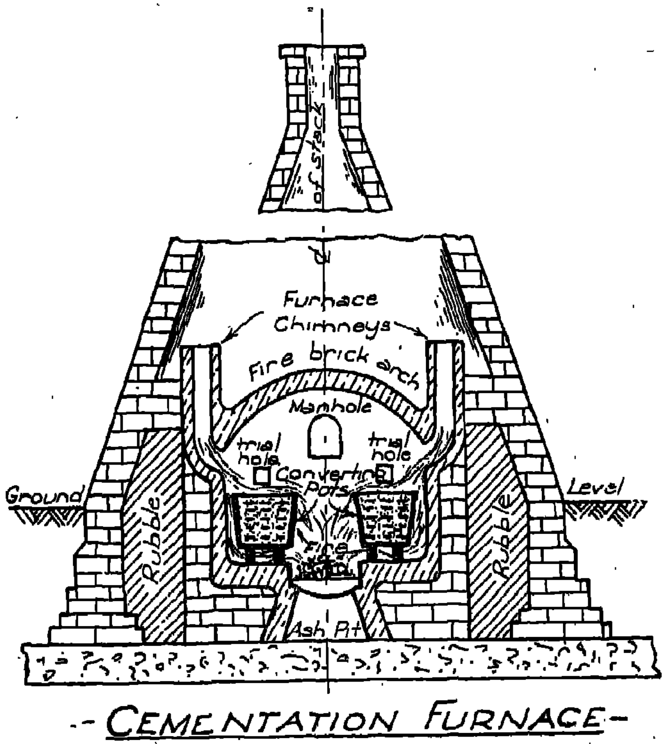
SECTIONAL VIEW OF OPEN HEARTH FURNACE

then added, in order to recarbonize the metal, by giving it the necessary proportions of carbon, silicon, manganese, etc., required to produce the desired grade of steel. After this has been done the furnace is tapped and the metal poured into ingot moulds for solidification prior to being rolled into desired shapes and sections.

A modern Open Hearth furnace will produce, in one heat taking from 10 to 13 hours, up to 250 tons of high-grade steel.

Mild steel has a medium crystalline structure and contains up to 0.35% carbon. It is malleable ductile and tenacious and is used for boiler plates, girders, rails, bolts, rivets, nails, etc.—and for most general constructional purposes.

4. **Tool Steel**: Tool or cast steel is today manufactured in the electric furnace. This modern method has almost entirely superseded the "*Cementation process*" whereby tool steel has been produced for years in England and the Continental countries. As the Cementation process was once used so extensively and small quantities of tool steel are still made by this method, a brief description should be of interest. In this process, bars of wrought-iron are subjected, at a comparatively low temperature, to the action of a substance rich in carbon. The bars are placed in fire-brick boxes, each layer separated by a layer of charcoal, and the boxes filled to within one inch or so of the top. The remaining space is filled with "*Wheel-swarf*," a mud-like mixture of fine sand and rust, which



-- CEMENTATION FURNACE --

later melts into a coarse glass and effectively seals the boxes.

The boxes are placed in the furnace and brought gradually to cementation heat (2,000° F.) and kept at this temperature for the time necessary to thoroughly carburize the bars. This takes from seven days for spring steel and up to ten days for high carbon steel. When the bars are cool and withdrawn from the box they are found to be covered with blisters (*Blister Steel*), containing from .65% to 1.5% carbon.

These bars of blister steel have no commercial value, so they are faggoted, reheated, hammered and rolled to form "*Shear*" steel. A repetition of this process gives "*Double Shear*" steel, but to obtain perfect uniformity of carbon distribution, which is lacking up to this stage, the blister steel is melted in a closed crucible to give *Crucible Cast Steel*, the grade depending upon the percentage of carbon contained.

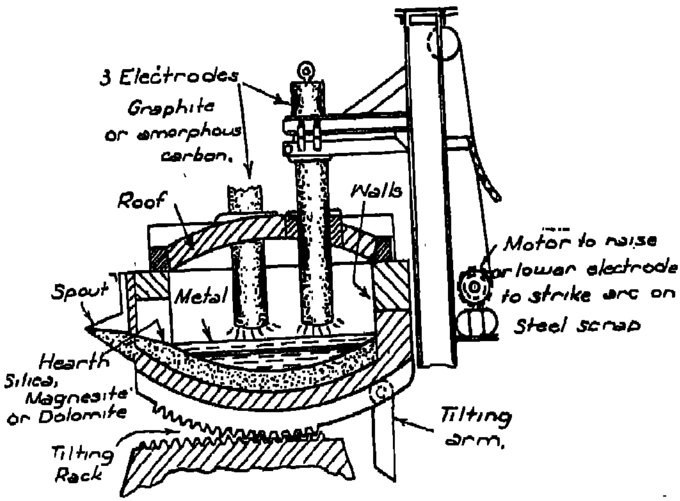
High carbon steels, *Self-hardening tool steel, stainless* and certain alloy steels are made by the addition of elements such as tungsten, nickel, cobalt and vanadium to mild steel in its molten state. To ensure absolute purity these metals are made in the electric furnace and to build up the quantity of metal in the furnace, stainless steel scrap and suitable alloy steel scrap is added as required.

Electric Furnaces.

1. **Electric Arc Furnaces:** These are of two types, viz. :—

(a) *Direct Arc*, where the current flows from one electrode to another and melts the steel by radiation.

(b) *Indirect Arc*, where the current flows from one electrode to another through the steel bath.



ELECTRIC ARC FURNACE.

These furnaces vary in capacity from 10 cwts. to 120 tons, and, depending on the size, etc., work between 65 and 260 volts, with amps from 0 to 20,000, at a temperature of approximately 1,570 degrees Centigrade.

Arc Furnaces may be either Basic or Acid in reaction.

The Basic Furnace has the hearth of burnt Dolomite or burnt Magnesite. The walls may be either Basic, *e.g.*, Dolomite or Magnesite bricks, or Silica, with generally a Silica brick roof.

This furnace can make any grade of steel from charges either of mixed steel scrap and/or liquid metal from another furnace. The main advantage of the Basic Furnace is the removal of Phosphorus and Sulphur to the minimum limits of .020% and lower.

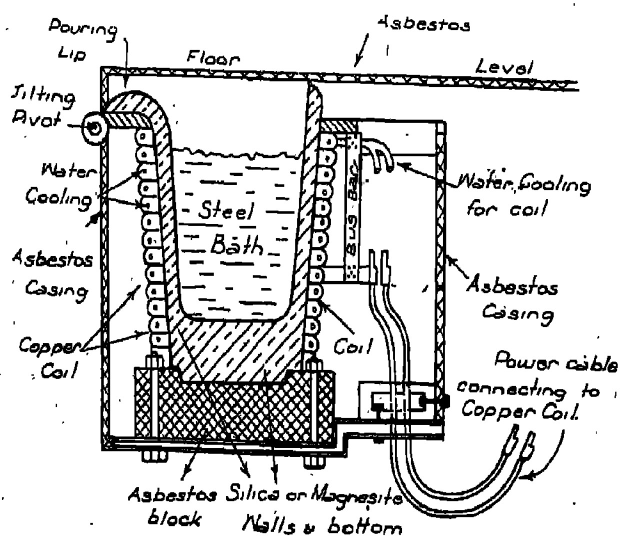
The Acid Furnace has the hearth of Silica bricks and Ganister with silica walls and roof. This furnace cannot remove Phosphorus and Sulphur and so must be charged with specially selected scrap.

The walls and roofs of both types of furnaces are changed every three to six weeks, but the hearths may last for several years.

In these furnaces *Slag* covers the steel at all times during melting and refining. Lime and Fluorspar being used for this purpose in the Basic type and Silica sand in the Acid.

Ferro Alloys, such as Ferro Chrome, Ferro Manganese, Ferro-Vanadium, Ferro-Tungsten and Ferro-Molybdenum, etc., are added to the molten metal in the furnace, during refining, in order to produce the required alloy steel with its necessary properties. The steel is tapped off into ladles and poured into ingot moulds or directly into casting moulds.

2. **Electric "High Frequency" or "Induction" Furnaces:** This furnace may be either Basic or Acid lined; no electric arc is used in this process, but the steel scrap is melted by induction current at 1,200 volts and 350 amps.



HIGH FREQUENCY FURNACE.

The *Basic type* is lined hearth and sides with Magnesite and the *Acid type* with Quartzite, both hearth and sides being replaced every one to three weeks.

As little refining can take place in this process, only selected steel scrap can be used, which will, in turn, produce a clean steel. This process is excellent for remelting expensive scrap, such as stainless and high alloy steels, where up to 95% of alloys, Chrome, Vanadium, Tungsten, Molybdenum, Nickel, etc., are recovered. Slag (lime or sand) covers the bath during melting. The steel is tapped into a ladle and poured into ingot moulds or castings.

The capacity of "Induction" Furnaces varies from 28 lbs. to 5 tons.

Tool steel is silvery grey to dark grey in colour, with a very fine crystalline structure. It is malleable, ductile, tenacious and the only metal that can be readily hardened and tempered. It is used for the manufacture of cutting tools, high-class tools of all descriptions, springs and permanent magnets.

Questions:

1. Name four ferrous metals.
2. Name the furnaces used for their manufacture.
3. What is the effect of the reduction or addition of carbon to these metals?
4. State the approximate quantity of carbon in each of the ferrous metals.
5. Name three elements used in the making of alloy steels.

ALLOY STEELS.

Most of the steels in use today are alloy steels. These are used extensively in the manufacture of machine parts which require extreme strength and elasticity for their weight. Most of these are manufactured either in the electric furnace or in the open hearth furnace by an addition of certain elements which improve the quality of the steel. For example, the addition of nickel greatly increases its strength, ductility and elasticity. Manganese and chromium are other elements added for alloying purposes.

Alloy steels, being harder than ordinary mild steel, are used for armour plate, projectiles, safes, etc.

Alloying Elements: The chief elements used in the manufacture of alloy steels, their characteristics and the properties they impart are as follows :—

1. *Chrome* is a bright, silvery white metal with a melting point of 1,832°C. It is very hard (almost as hard as a diamond) and as tarnish proof as gold. Chromium increases the hardness, tenacity and resistance to corrosion of the resultant alloy without increasing the brittleness, although chromium itself is very brittle and can be easily broken. It is used in the manufacture of high speed tool steels, stainless steel, rustless iron, safes, projectiles, armour plate, motor car and aircraft engines, etc.

Note: The word chromium is derived from the Greek word "chroma" meaning "colour." Compounds of chromium have a colour range covering the entire spectrum. The red of the ruby and the green of the emerald are both due to traces of chromium.

2. *Nickel* is a silvery-white metal with a yellow tinge, having a melting point of 1,472° C. It increases the elasticity, tenacity, hardness and endurance of its alloys. It also improves the corrosion and oxidation resisting properties.

3. *Tungsten* is a bright, steel-grey metal which is extremely hard and very heavy, with a melting point of approximately 3,330° C. It is used for the filaments of electric lamps and as an alloying element in the making of high-speed steel and other cutting alloys. It imparts to its alloys the property of "red-hardness," which is the ability to keep its cutting edge when working at a temperature of red heat.

4. *Cobalt* is a bluish-white metal with a melting point of 1,500° C., and next to iron is the most magnetic of metals. It is used for alloying in the making of high-speed steels and imparts an ability to resist wear at high temperatures.

5. *Vanadium* is a brilliant white metal which is very hard with a melting point of 1,728° C. It has an important influence on the hardness of high-speed steels and its alloy steel is largely used in the manufacture of tools.

6. *Manganese* is a greyish metal, very hard and brittle with a melting point of 1,255° C. It is an important constituent in the manufacture of many ferrous and non-ferrous alloys to which it imparts hardening properties. It also acts as a deoxidiser to the steel in its molten state.

7. *Molybdenum* is a silvery-white malleable metal with a melting point of 2,472° C. It is used in its pure state as a wire that will resist high temperatures. As an alloying agent it is used in the making of special steels and cast-irons. It improves the cutting efficiency of high-speed steels at ordinary and high temperatures.

8. *Titanium* is a hard, brittle metal with a melting point of 1,816° C. It is useful in the manufacture of carbides and stainless steels and helps to prevent the oxidation of steel in its molten state. It is used also in the manufacture of non-ferrous alloys such as aluminium bronze.

9. *Tantalum* is a steely-blue metal, relatively soft and malleable, with a melting point of 2,866° C. It is an

excellent acid resister and is used largely in the manufacture of high-speed steels, acid-resisting alloys and carbide alloys. The tensile strength is higher than that of either steel or platinum.

10. *Zirconium* exerts much the same influences in the manufacture of alloy steel as does titanium in that it helps to prevent oxidation of the metal in its molten state. It counteracts the adverse effect of sulphur on the physical properties of steel and is used also in the enamelling process. It has a melting point of 1,727° C.

Note : Most of the above elements are combined with iron before being added to the molten steel, thus they are added in the form of Ferro-chrome, Ferro-vanadium, Ferro-manganese and so on. This has the effect of reducing the cost and facilitating melting.

Cutting Steels and Alloys : The metals most commonly used for cutting tools are set out as follows :—

1. *Carbon Steel* is used for the making of tools that need to keep a keen edge that is not easily dulled. It is readily hardened and tempered to the degree necessary for the purpose for which it is to be used. It has a tendency, however, to lose its temper, hardness and consequently its cutting edge when subjected to excessive frictional heat, and for this reason it has been gradually superseded by special alloy steels.

2. *High-speed Steel* is a self-hardening steel, containing tungsten, molybdenum with small percentages of chrome, vanadium and cobalt. It is readily forged to shape for use as cutting tools. A lot of its efficiency depends upon correct treatment during the forging and hardening process, for if hardened and tempered correctly, a tool made of this metal will be unaffected by ordinary cutting temperatures and retain a keen edge indefinitely.

3. *Non-ferrous Alloys* : Stellite is the best known in this group. It consists of tungsten, chromium, cobalt and molybdenum in varying proportions. Tools made of stellite can be used at cutting speeds approximately

50% greater than those for which high-speed steels can be used. These tools are extremely brittle and great care must be taken not to damage or chip the cutting edge.

4. *Cemented Carbides*: These tools contain tungsten, cobalt, carbon and sometimes tantalum and titanium in different proportions and are usually made in the form of small tips, brazed to shanks made of medium carbon, but tough steel. They are extremely hard and brittle, necessitating special grinding appliances and can be run at speeds approximately 3½ times faster than those used for high-speed steels.

Special Alloys

Two other special purpose metals are :—

(a) Monel metal.
(b) Stainless steels.

(a) *Monel metal* is a natural, nickel-copper alloy, containing nickel, copper, iron and manganese in varying proportions, with a small percentage of carbon. It has a silvery lustre and a melting point of 1,343° C., is tenacious, malleable, ductile, forgeable, machinable, casts well and resists corrosion. It can be joined readily by welding, brazing or soldering.

Monel metal is used in the manufacture of hospital equipment, cheap jewellery and resistance wire.

(b) *Stainless steels*: Alloys containing iron, chromium and nickel are grouped under this general heading. There are three main groups, viz :—

(1) Chromium-steel (with a moderately high carbon content and used chiefly in the manufacture of cutlery).

(2) Chromium-steel (with under 0.12 per cent. carbon).

(3) Chromium-nickel (with a variable carbon content. Molybdenum may be added to the metals in this group to ensure resistance to corrosion when brought into contact with certain chemicals).

These steels are ductile, tenacious, malleable, forgeable (at special temperatures), machinable, weldable and can be silver soldered. They are more resistant than ordinary steels to oxidation and corrosive attack by a wide range of chemicals.

Stainless steels have a melting point ranging from 1,370° C. to 1,400° C., and with the exception of the chromium-nickel group are tempered after hardening at temperatures varying in accordance with the physical properties required such as tensile strength and ductility. They are used for making tools, cutlery, hospital, dairy, brewery and cannery equipment, motor-car and aircraft parts, etc.

Questions :

1. What do you understand by the term "Alloy steels" ?
2. Name any two elements used for alloying and state their advantages in this respect.
3. Why is carbon steel being superseded as a metal used for making cutting tools ?
4. What are the special advantages of "Stellite" ?
5. Name the three groups into which Stainless steels may be divided.

NON-FERROUS METALS.

Under this heading will be treated those metals which are free from iron and are obtained from the earth in the form of ores which are treated to extract the metals they contain. They differ from alloys in that, although alloys are non-ferrous metals, they are merely combinations of two or more of these pure metals.

The most common non-ferrous metals used commercially are :—

1. Aluminium.	6. Mercury.
2. Antimony.	7. Platinum.
3. Copper.	8. Silver.
4. Gold.	9. Tin.
5. Lead.	10. Zinc.

Their chief properties, characteristics and uses are as follows :—

1. **Aluminium** is greyish-white in colour, malleable, ductile, tough, very light and possesses excellent alloying properties. It has a tenacity of 5 to 10 tons per square inch, is a good conductor of heat and electricity, makes good castings and does not corrode. Aluminium, in its pure state, is used, largely in the form of sheets, rods or castings, for making cooking utensils, etc., and on account of its strength and lightness, for aeroplane and motor bodies and parts. It is also used as a constituent in the making of certain brasses, bronzes and steel alloys.

2. **Antimony** is whitish in colour. It is very brittle and possesses the remarkable property of expanding slightly upon cooling, a property which it imparts to its alloys. It is used for hardening other metals, notably lead and tin for type metal, and copper and tin for Britannia metal, also as a constituent in the making of anti-friction metals for machinery bearings.

3. **Copper** is one of the oldest metals known to man. It is reddish-brown in colour, malleable, ductile, very tenacious and an excellent conductor of heat and electricity. Its high ductility and conductivity make it particularly suitable for the making of wire cables to conduct electricity. It is used largely, with tin and zinc, as a constituent in the manufacture of bronze and brass. Copper, by reason of its malleability and good colour, is used extensively in the handicraft room for making bowls, ornaments and general repoussé work. It quickly hardens when worked by hammer or mallet, but can be readily annealed by heating to a dull red and plunging into water.

4. **Gold** is yellowish in colour and extremely heavy. It is the most malleable of all metals and can be rolled into sheets one-forty thousandth of an inch in thickness, the sheets being so thin that it would take twelve hundred of them to equal the thickness of one sheet of ordinary writing paper. Gold is used chiefly for the making of coins, when it is alloyed with a small percentage of copper or silver, for making jewellery and, in the form of gold leaf, for ornamental gilding.

5. **Lead** is a bluish-grey colour. It is heavy, soft and malleable, possessing little or no tenacity or elasticity. On account of its ability to resist corrosion it is used, in sheet form, by plumbers for roofing purposes and general sanitation work. It is also used as a constituent, with tin and antimony, in the making of solders and anti-friction metals.

6. **Mercury** is silvery-white in colour and is very heavy. It has the peculiar property of being liquid at ordinary temperatures and, by reason of the fact that its coefficient of expansion is remarkably uniform, it is used in the construction of scientific apparatus, such as thermometers, barometers, etc. It is also used as a constituent with tin, lead and bismuth in the production of low melting point alloys for fire sprinklers, etc.

7. **Platinum** is silvery-grey in colour and is the heaviest of the known metals. It is very hard, ductile and difficult to melt. It has many uses, but these are limited by its extremely high price, and so they are chiefly confined to parts of the more expensive electrical apparatus.

8. **Silver** is a silvery-white colour, is soft, malleable, ductile and the best known conductor of heat and electricity. Its use in this latter respect, however, is limited, owing to its high cost. Silver is used for a variety of purposes, the most important probably being for coinage and jewellery, when it is usually alloyed with copper. It is used also in electrical, radio and radar instruments, for bearings in aircraft engines, for silvering mirrors and searchlight reflectors, for silver-hardening steel, for surgical purposes and for silver plating.

9. **Tin** is silvery-white in colour, very malleable and ductile, but possesses little tenacity. This metal has very little use in its pure state, except in electrical condensers and as tinfoil, its high degree of malleability allowing it to be rolled into very thin sheets. It is used as a constituent with lead and copper in the making of such alloys as solder and bronze and for coating mild steel in the manufacture of tinplate.

10. **Zinc** is a greyish-white metal, malleable and ductile. It resists corrosion better than most metals and so is used for guttering, pipes and for coating mild steel in the manufacture of galvanised iron. It is also used in the construction of batteries for generating electricity.

SUMMARY.

Non-Ferrous Metals are elements which are free from iron. They differ from alloys in that they consist of one element entirely, whereas an alloy is a combination of two or more non-ferrous metals. The most common non-ferrous metals, with their properties and uses, are :—

Aluminium is greyish-white, malleable, ductile and very light. It is used for making cooking utensils, aeroplane and motor bodies and parts and for alloying with other metals.

Copper is reddish-brown, malleable, ductile, tenacious and a good conductor of heat and electricity. It is used for making electric cables, for repoussé work and for alloying with tin and zinc to make bronze and brass.

Lead is bluish-grey, heavy, soft and malleable. On account of its anti-corrosion properties it is used for roofing and general sanitation work, also for alloying with tin and antimony in the making of solder and anti-friction metals.

Silver is silvery-white, soft, malleable, ductile and the best known conductor of heat and electricity. It is used for the making of coins, jewellery and electrical apparatus.

Tin is silvery-white, very malleable and ductile. It has very few uses in its pure state, except as tinfoil and in electrical condensers. Its main use is for alloying with tin and copper, in the production of solders and bronze, and for coating mild steel in the manufacture of tinplate.

Zinc is greyish-white, malleable, ductile and has excellent anti-corrosion properties. For this latter reason, it is used for guttering, pipes, etc., and for coating mild steel in the manufacture of galvanised iron.

Questions :

1. In which way do non-ferrous differ from ferrous metals ?
2. How do non-ferrous metals differ from alloys ?
3. Name four non-ferrous metals.
4. Which is the most malleable of the non-ferrous metals ?
5. What is the value of anti-corrosion properties in a metal ?

ALLOYS.

The alloys treated under this heading are of the non-ferrous variety. They are combinations of pure non-ferrous metals, with properties differing, to some extent, from those of their constituents. It is thought that, with the possible exception of copper, alloys were the earliest metals known to man.

They possess many of the properties of the constituent metals, also many additional properties, such as :—

(a) A lower melting point.

(b) Greater hardness and toughness.

(c) Increased resistance to oxidization.

(d) Better casting qualities.

Alloys, generally, are more tenacious, ductile and harder than the metals composing them. The fusing point is usually lower than the average melting temperatures of their constituents. In the case of solder, for example, which melts at 240° F., the melting point is even below that of the lowest of its constituents as shown :—

CONSTITUENT METALS	MELTING POINT	AVERAGE	MELTING POINT of resultant alloy (SOLDER)
Lead	620° F.		
Tin	475° F.	527° F.	240° F.
Bismut	487° F.		

Alloys may, for convenience, be divided into five groups, viz. :—

1. Copper-Zinc alloys.
2. Copper-Tin alloys.
3. Tin-Lead alloys.
4. Antimony alloys.
5. Aluminium alloys.

The properties and uses of the most commonly used alloys in each group are as follows :—

1. **Copper-Zinc Alloys :** The alloys in this group are combinations of copper and zinc in varying proportions. They range, in composition, from 90% copper and 10% zinc, to 20% copper and 80% zinc. The two most commonly used, however, are brass and muntz metal.

Brass (English standard)—contains 66.6% copper and 33.3% zinc. It is yellowish in colour, malleable and produces sound, clean castings. It is used extensively in sheet form, its colour and nature rendering it suitable for the making of bowls, ash-trays, etc., and for general repoussé and ornamental work.

Muntz Metal contains 60% copper and 40% zinc is yellowish in colour, malleable, ductile and resists corrosion. It is used largely in sheet form for sheathing the bottoms of boats.

2. **Copper-Tin Alloys**—commonly termed bronzes—range in composition from 90% copper and 10% tin, to 66.6% copper and 33.3% tin. The most common of the copper-tin alloys are gunmetal and bronze.

Gunmetal contains 90% copper and 10% tin and is yellowish-grey in colour. It is harder than copper, is fusible and tenacious, possesses excellent anti-friction properties and makes good castings. Gunmetal is used for strong castings, being stronger than cast-iron, also for bearings and parts of machinery exposed to corrosion.

Bronze contains 85% copper and 15% tin and has properties similar to gunmetal. It is commonly used for statuary and bell castings. Oxidized bronze has almost entirely superseded brass in modern architecture, and it does not need so much care and attention and is much more attractive in appearance.

3. **Tin-Lead Alloys** have a greater tenacity, are harder, more fusible and have a lower melting point than either tin or lead separately. The variation in the melting point depends entirely upon the percentage of tin in the alloy, the higher the percentage the lower the melting point. An example of this is shown in the following table :—

ALLOY	Percentage of LEAD	Percentage of TIN	MELTING POINT
Plumber's Solder ...	66.6	33.3	480° F.
Tinman's Solder ...	50	50	425° F.
Fine Solder	33.3	66.6	365° F.

The most common alloys in the Tin-Lead group are Solder and Pewter.

Solder: Solders of various types are made by varying the percentages of tin and lead in their composition. These alloys are malleable and ductile, with a low melting point, the latter dropping as the percentage of tin rises. They are used for soldering metals where the strength of the joint is not essential, and are usually applied with a copper soldering bit; they are used also for "wiping joints" in plumbing work.

Pewter contains 80% tin and 20% lead, has a silvery-white colour and properties somewhat similar to solder. It is used in the manufacture of various domestic utensils, such as drinking mugs and plates, and for decorative purposes.

Fusible Alloys: These are composed of tin and lead with the addition of bismuth, or bismuth and mercury, these latter metals having the effect of lowering the melting point considerably. These alloys are used as solder for joining pewter and as quick melting metals for fire sprinklers, etc.

4. **Antimony Alloys:** These consist of tin, lead and antimony, or tin, copper and antimony, in varying proportions. Antimony tends to harden its alloys and imparts to them its peculiar property of expanding slightly on cooling. The most common alloys in this group are White metal and Babbitt's metal.

White Metal is silvery white in colour. It is composed of 75% lead, 20% antimony and 5% tin; has excellent alloying properties, wears well and is readily cast. It is used extensively for lining engine and machinery bearings.

Babbitt's Metal is silvery-white in colour with a slight yellow tinge. It is made with varying proportions of its constituent metals, but in the main consists of 83.4% tin, 8.3% antimony and 8.3% copper. It has excellent anti-friction properties and, therefore, is used for lining machinery bearings, etc.

5. **Aluminium Alloys:** Aluminium is alloyed with several metals, *e.g.*, with copper in the production of aluminium bronze, and with copper, magnesium and manganese in the production of duralumin.

Duralumin is silvery-grey in colour, and is composed of:—

Aluminium	94.50%
Copper	3.80%
Magnesium	0.95%
Manganese	0.75%

Duralumin is very light and, if properly tempered, has a very high tensile strength. It is widely used in the construction of aircraft of all descriptions.

Hiduminium is the name given to a series of aluminium alloys used by the Rolls-Royce Engineering Company in the manufacture of aircraft engines. Each alloy in this series has special uses and is given a number, e.g., RR56 and RR59, the former being a forgeable alloy used for the manufacture of airscrews, while the latter is used mainly for pistons. The tensile strength of hiduminium is increased considerably by subjecting it to heat treatment.

Magnalium contains 95% aluminium and 5% copper, magnesium and nickel in varying proportions. It has excellent casting properties and is used largely in the manufacture of crankcases for motor and aircraft engines.

Elektron Metal is a very light alloy containing 94% magnesium, 5% zinc, and 1% aluminium and copper in varying proportions. Owing to the inflammable nature of this alloy great care must be exercised when casting or machining it. Elektron is used extensively in sheet form for aircraft body construction, also for engine parts such as crank and gear cases and connecting rods.

SUMMARY.

The common alloys are combinations of pure, non-ferrous metals, with properties differing somewhat from those of their constituents. Alloys are usually more tenacious, ductile and harder than the metals composing them, with a melting point generally lower than the mean of their constituents.

Alloys may be conveniently divided into five groups :—

1. Copper-Zinc alloys.
2. Copper-Tin alloys.
3. Tin-Lead alloys.
4. Antimony alloys.
5. Aluminium alloys.

Some of the most commonly used metals in these groups are as follows :—

Brass : is a copper-zinc alloy, is yellowish in colour, malleable, ductile and casts well. It is used extensively in the form of sheets, rods and tubes.

Muntz Metal : is a copper-zinc alloy, malleable, ductile and resists corrosion. It is used largely in sheet form for sheathing the bottoms of boats.

Gunmetal : is a copper-tin alloy, yellowish-grey in colour, hard, tenacious and fusible. It possesses excellent anti-friction properties and casts well. It is used for strong castings and machinery bearings.

Solder: is a tin-lead alloy. It is malleable and ductile, with a low melting point. It is used for soldering metals, when the strength of the joint is not essential, and for "wiping joints" in plumbing work.

White Metal: is an antimony alloy which possesses excellent anti-friction properties, wears well and is readily cast. It is used for lining engine and machinery bearings.

Duralumin: is an aluminium alloy which is very light and, if well-tempered, possesses a very high tensile strength. It is used in aircraft construction.

Questions:

1. What are alloys?
2. What advantages are gained by alloying metals?
3. Name three of the alloyed metal groups.
4. Name one metal from each group.
5. State the uses and properties of each metal named in No. 4.

HEAT TREATMENT OF METALS.

Although it is possible to master the treatment of simpler and less expensive pieces of work without much difficulty, it should be thoroughly understood that the proper treatment of metals with heat presents many problems which can only be solved by a wide and varied experience in the art.

Metals are usually treated by heat in order that they may be more easily worked, or offer greater resistance to general wear and tear. The most common methods used in attaining these objects are :—

(a) Annealing.
(b) Hardening.
(c) Tempering.
(d) Case-hardening.

(a) **Annealing** is the term generally applied to the softening of metals although the process may also be used for the purpose of relieving stresses, refining the crystalline structure or altering the toughness or ductility of a metal. It often happens that metals, particularly steel, need to be softened in order that they may be worked upon by edge tools or files. The hammering, rolling and bending of certain metals, such as copper and brass, tend to set up internal stresses which must be relieved.

The annealing of *iron* and *steel* is effected by heating to redness and then cooling out slowly. In the case of cast steel it is advisable, after heating, to bury the metal in cinders or lime, as this retards the cooling and helps to retain the full carbon content.

Copper and *Brass* are annealed by heating to redness and cooling by plunging into water. They may also be cooled slowly as the rate of cooling in no way affects the degree of softness; the former method, however, is usually preferable for convenience.

The softer metals, such as *Tin* and *Lead*, may be annealed sufficiently for working purposes, by heating in boiling water and cooling out in the air.

(b) **Hardening**: Cast steel is the only metal that can be readily hardened and tempered sufficiently to cut other metals. If pure iron is heated and then cooled it becomes soft, but the presence of carbon in the metal, no matter how small the percentage, entirely reverses this, with the result that, upon the sudden immersion of steel into water, the metal immediately becomes extremely hard and brittle.

Cooling Media: The liquids generally used for cooling purposes are Water, Brine and Oil.

Water: Is the liquid most commonly used. It should be clean and cool, for the successful hardening of steel depends very largely on the cooling liquid as well as the manner in which the work is presented to it.

Brine: When salt is added to water, it is called brine. The advantage of this medium is that when the metal is quenched it intensifies the hardening effect.

Oil: Cooling in oil is considered superior to water or brine for many classes of work. Its advantages lie in its softer action and more rapid conduction of the heat from the metal. Cotton seed, or sperm oil are those most generally used. Springs of all classes are usually hardened in an oil bath.

Mercury is a more rapid cooling medium than either water, brine or oil. It may be used for quenching small articles when extreme hardness is required.

(c) **Tempering**: Although often referred to as the same, hardening and tempering are quite different. By hardening a metal it is transformed from a relatively soft material to one which is exceedingly hard, yet brittle and weak, but by tempering, this hardness is reduced to the degree required for a certain class of work, and much of the original strength and toughness restored. It should be readily seen, then, that the degree of hardness of a metal must be slightly greater than that required in the finished article so that, when tempering, it may be reduced.

Method of Tempering: To harden and temper a metal, *e.g.*, a cast steel chisel, the cutting edge is first heated to a black heat and then on to a red heat for about one inch or so from the point. About half of this heated portion is then hardened by cooling out quickly in clean water, preferably warm, the point being moved about in the water to ensure uniform cooling.

The process so far has only resulted in the hardening of the point which would be too brittle for use, so the next step must be to reduce this hardness and toughen the metal by tempering. So when the point is withdrawn from the water it is quickly rubbed with a piece of sand-stone or some such abrasive, to brighten the surface, so that the tempering colours, as they flow towards the point, may be clearly seen. When the desired colour reaches the edge it is arrested by quickly plunging the whole chisel into water. By this method the hardening and tempering of the tool are both performed in the one operation.

The following table gives some indication of the temperatures and the uses of carbon steel, at the various tempering colours :—

COLOUR	Temperature deg. Fah.	USES
Light Straw ...	450°	Scribers, Razors, Turning and Planing Tools.
Medium Straw ...	470°	Knives, Shears, Cold Chisels for cutting hard metals.
Dark Straw ...	490°	Drills, Dies and Taps.
Brown	500°	Woodworking Tools, Reamers, Hammer Faces and Panes.
Purple	530°	Centre Punches, Cold Chisels for cutting soft metals.
Blue	570°	Saws, Springs, Screwdrivers.

(d) **Case Hardening:** The method of case-hardening metals is similar, in principle, to that of making cast steel from wrought-iron by the cementation process. Mild steel and wrought-iron are the only metals suitable for this treatment, which is a process whereby the surface of the metal is converted into tool steel to depths varying from $\frac{1}{64}$ to $\frac{1}{4}$ inch, and afterwards hardened.

Case-hardening is effected by heating the metal in contact with some material rich in carbon which will give up its carbon to the metal. The two most common methods in general use are:—

1. The articles to be treated are packed in an iron case (hence the term "case-hardened") with animal charcoal, such as charred leather, bones, etc. The case is sealed with a lid to prevent the escape of gases and is placed in a furnace where it is slowly heated to a dull red colour, at which temperature it is kept for the length of time, varying from two hours to several days, necessary to give the metal the desired depth of carbon. After being removed from the furnace, the case is opened and the articles plunged into water for cooling and hardening.

2. A simpler process, and one that can be used in the workshop, is to heat the articles to be treated to a bright red colour and then cover them with powdered prussiate of potash (*potassium cyanide*), afterwards reheating and cooling them quickly in water. The hardened surface thus obtained is very thin and the metal usually needs several applications of the treatment before the required thickness is obtained.

The chief advantage of case-hardening metals is that the outside surface of the metal is converted into cast steel, with its strength and hardness, while the inside, or core of the metal, remains soft and ductile. This is particularly useful where a hard-wearing surface is needed in an article subject to shock. The gear wheels in motor cars provide an excellent example of this. Spanners, set screw ends and some types of "V" blocks are also typical examples of case-hardening.

Nitrogen Case-hardening—"Nitriding": The surface of certain alloy steels can be made extremely hard and

non-brittle by treatment with ammonia gas at a temperature of 1,050° F., at which temperature they absorb nitrogen from the gas. The only steels that can be successfully treated are those containing either aluminium (.5% to 2%) or chromium, or its properties (from .5% to 4%). Other alloys or carbon steels are unsuitable.

Before using this process it is first necessary to "stabilize" the metals to be treated by annealing in order to relieve any stresses or strains that may have been previously set up by forging, machining, etc.

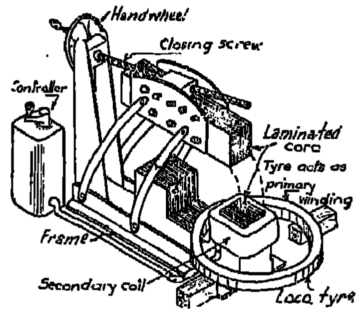
The parts to be treated are then placed in an air-tight box fitted with inlet and outlet tubes for the passage of the gas, the flow of which is regulated by means of a needle valve and must be fairly even throughout the process. In order that the gas may circulate freely the articles being treated rest on a bed of nickel-plated wire-netting. The gas box is next placed in an electric furnace and the whole subjected to a temperature of 1,050° F. for a period of from two hours to four days, depending on the depth of hardening required.

Where it is required to have certain parts of the metals remain soft, perhaps for machining purposes, this is achieved by plating the part concerned with nickel or copper when it will be unaffected by the action of the gas.

Heating by Induction: This is a new and versatile industrial process in which metals are brought, if necessary, to welding heat by subjecting them to the action of an electric current, passing through water-cooled coils. These induction heating coils carry a high frequency alternating current which sets up a magnetic field around the coil and with each alternation of the flow the magnetic field is reversed in direction. If a metal object is placed either inside or around the coil, this continuing process of alternation induces an alternating current, which in turn, sets up violent agitation within the atomic particles of the metal, causing them to get hot.

Speed and convenience are the chief virtues of induction heating. When used for surface hardening the coil brings

the surface of the metal almost instantly to white heat, whereupon the metal is quenched quickly, rendering the surface hard, brittle and wear-resistant, leaving the unheated core practically unaffected, unhardened and still retaining its toughness and elasticity.



INDUCTION HEATING MACHINE

Another method of induction heating, involving the principle of the transformer, is one in which a magnetic field is induced in a circular iron core by a large coil of wire and transformed to a heavy amperage current in any circular iron or steel object by placing it inside this field. The heating of the object is caused by the resistance offered by it to the electric current. In effect, the circular iron object actually becomes one turn of a secondary coil which is short-circuited.

SUMMARY.

Metals are usually treated by heat in order that they may be more easily worked, or, on the other hand, that they may offer greater resistance to general wear and tear. The most common methods used in attaining these objects are as follows :—

Annealing : is the term applied to the softening of metals.

Iron and steel are annealed by heating to redness and then cooling out slowly by burying in cinders or lime.

Copper and brass by heating to redness and quenching in water.

Tin, lead and zinc by heating in boiling water and cooling in the air.

Hardening: Cast steel is the only metal that can be readily hardened and tempered sufficiently to cut other metals. It is hardened by being heated to redness and quenched quickly in water.

Tempering: The simple hardening of cast steel renders it too brittle for use in the form of tools, therefore this hardness must be reduced and the metal made more elastic by tempering. This is done by a reheating and cooling process.

When steel is heated certain colours appear on its surface. These denote certain temperatures and various stages from extreme hardness to softness. It is possible to arrest any degree of temper by quenching the metal in water when the colour denoting that degree is reached.

Case-hardening: Is a process of converting the surface of mild steel and wrought-iron into tool steel. This is effected by heating these metals in contact with some material, rich in carbon, which will give its carbon to them. Case-hardened metals have the advantage of possessing the hardness and strength of tool steel on the outside, with the ductility and elasticity of the mild steel in the inside. Typical examples of case-hardened articles are set screw and spanner ends and gear wheels for motor cars.

Questions:

1. What is meant by annealing?
2. How would you anneal copper and brass?
3. Explain the difference between hardening and tempering?
4. What is meant by case-hardening?
5. What advantages are gained by case-hardening metals?

THE MANUFACTURE OF TINPLATE AND GALVANISED IRON.

Tinplate is thin sheet iron or steel coated with pure tin. The process of tinning iron, to protect it from rust, was known as far back as the fifteenth century, but it was not introduced into England until towards the end of the eighteenth century.

Tinplate is not much used as a structural material, but, owing to the fact that it is not acted upon by vegetable acids or fruit juices, it is used extensively for the manufacture of containers for foodstuffs, such as jam, preserved fruits, fish, milk, biscuits, etc.

The process of manufacture is as follows: Bars of mild steel or wrought-iron are heated and rolled into thin sheets by a doubling and re-rolling process. These sheets, after being sheared to the required sizes, are pickled in dilute sulphuric acid, scoured and annealed. They are then subjected to cold rolling to improve the surface; this makes a second annealing and pickling necessary. After the second pickling, in very dilute acid, the sheets are dipped into a bath of melted tallow, or palm oil, which acts as a flux, and then into a bath of molten tin which is covered with grease or zinc chloride to prevent oxidisation. To perfect the tin coating the sheets are dipped into several successive baths. Finally to improve the surface and to remove any surplus tin, the sheets are passed through a series of rollers running in a grease bath. After being cooled, the sheets are polished with wool or bran to produce a bright surface and before packing are wiped lightly with oil.

Galvanised Iron: The coating of iron and steel with zinc is called galvanising, and is one of the most useful discoveries of modern times. The word was derived from the name of *Luigi Galvani* (1737-1798), who, by experimentation, discovered a method of depositing zinc on iron by electricity. This method, however, was

found to be very expensive, and so has been superseded almost entirely by the hot galvanising process in use to-day.

In this process the bars of mild steel or wrought-iron are rolled into sheets (black iron sheets), in a manner similar to that used in the manufacture of tinplate. These sheets are then cleaned and all scale, oxides, etc., removed by a process of pickling in an acid bath consisting of a mixture of sulphuric and hydrochloric acid. Afterwards they are washed and scoured with sand. They are then passed by a series of rollers through a bath of molten spelter (consisting mainly of zinc—about 93%), the surface of which is covered with a layer of ammonium chloride (sal-ammoniac). This latter substance acts as a flux, which induces the coating of the iron by the zinc and protects the molten zinc from oxidisation through contact with the air. A small percentage of tin (2% to 3%) is added to the zinc bath to produce the large crystalline spangles noticed on the finished sheet. As the sheets are drawn from the bath they pass through rollers which squeeze off any surplus zinc and improve the adherence. The proportion of zinc adhering to the iron is usually reckoned in ounces per square foot, two ounces being a good average coating.

A large proportion of the galvanised iron manufactured is corrugated to increase its strength and to prevent it buckling when used for walls and roofing purposes. Many articles are made from sheet galvanised iron, but quite often articles, such as buckets and dippers, are made from the black iron sheets and afterwards dipped in the galvanising bath to give them the protective covering.

Galvanised iron is used largely for structural purposes, such as roofing, guttering, downpipes, etc., on account of its ability to resist corrosion for, if well-galvanised, it will withstand weather indefinitely.

Zinc anneal: Is produced by subjecting sheets of galvanised iron to a further heat treatment. Immediately the sheets leave the galvaniser they are passed through

a furnace having a temperature of 650° F. This heat fuses the zinc into the pores of the mild steel thus forming a zinc-iron (intermetallic) alloy on the surface. As the sheets are withdrawn from the furnace they are passed through rollers. The chief property imparted by this treatment is the improved adherence of the zinc coating which will not flake when the sheets are worked.

Terne Plate: Terne plating is the coating of mild steel sheets with a lead alloy for the protection of the surface. The process of manufacture is very similar to that of galvanising. The metal bath contains approximately 85% lead and 15% tin (American standard 75% lead and 25% tin) to give a covering weight of one ounce of alloy per sq. ft., the flux used being a combination of zinc chloride and ammonium chloride.

Sherardising: is a process somewhat similar to galvanising, the articles to be treated, *e.g.*, small castings, gutter bolts, etc., are pickled in an acid bath and then washed thoroughly with water after which they are packed in an air-tight retort containing zinc powder. This retort is revolved slowly in a furnace at a temperature of 750° F., during which time the zinc impregnates the surface of the iron, thus forming a zinc-iron (intermetallic) alloy, with a thin coating of zinc on the outer surface. If the retort is not absolutely air-tight it is advisable to add a small amount of powdered charcoal to the zinc in order to counteract the formation of zinc oxide.

Calorising: is a process similar to sherardising in principle with the exception that aluminium powder is used instead of zinc, the coating in this case being an intermetallic alloy of iron and aluminium.

Metal Spraying: This is a process whereby a thin coat of metal such as zinc, tin, brass or bronze is applied to the surface of another metal or to that of such substances as wood, glass or cloth.

The surface to be treated must be free from oil or grease and must be thoroughly cleaned, preferably by sand-blasting. The metal is sprayed on by means of a special spray gun in a manner similar to that used for spray painting. The gun is charged with a spool of the required covering metal. This metal is made to pass over a very hot flame which causes it to melt whereupon a jet of compressed air immediately atomizes it and forces it on to the surface to be treated.

Zinc is the metal most frequently used in this process on account of its ability to resist corrosion and so is largely used for covering work exposed to the weather.

Electroplate: Is made by depositing one metal held in solution on to the surface of another metal by an electrical action.

It is possible by this process to plate with a wide range of metals, including copper, nickel, cadmium, chromium, silver, gold, tin and zinc. The metals most commonly used, however, are copper, nickel and chromium; of these three metals copper is the one most readily deposited. Nickel plates best over copper, consequently a surface to be treated is first plated with copper. Again, as chromium plates best over nickel, a surface to be chromium plated is treated first with copper, then with nickel and finally with chromium to give the finished surface.

The use of chromium as a decorative and wear resisting coating for household furnishings and appliances and for motor car fittings has almost entirely superseded that of nickel, also because of the extreme hardness of the surface gear wheels, dies and gauges are frequently so treated and are consequently more wear resistant and tougher than ordinary case-hardened steel.

Electroplating is used extensively for decorative purposes such as jewellery, ornaments, window fittings, etc., for increasing the surface hardness of metals and as a protection against corrosion and the action of certain acids.

Questions:

1. What is tinplate ?
2. What is galvanised iron ?
3. How was the name "Galvanised" derived ?
4. How are the black iron sheets cleaned prior to being coated with tin, zinc or lead ?
5. State the chief uses of tinplate, galvanised iron and terne plate.

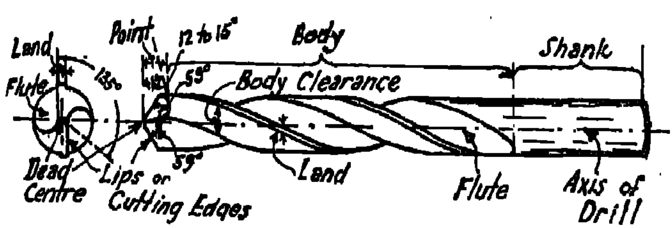
DRILLS AND DRILLING.

The operation of boring holes in metals is called "**Drilling,**" and the tools used by the engineer and metal worker for this purpose are known as "**Drills.**" There are various kinds of drills in common use, the principal types being as follows :—

(a) The Twist Drill.
(b) „ Flat Drill.
(c) „ Straight-fluted Drill.
(d) „ Pin Drill.
(e) The Flat-ended Drill.
(f) „ Centre Drill.
(g) „ Countersinking Drill.
(h) „ Cutter Bar.

The details and uses of these are :—

(a) **The Twist Drill :** This is the drill most frequently used in modern workshop practice. Twist drills are made either from high carbon or high-speed steel, and range in size from $\frac{1}{64}$ of an inch up to 3 inches in diameter. They consist of three main parts—the point, body and shank.

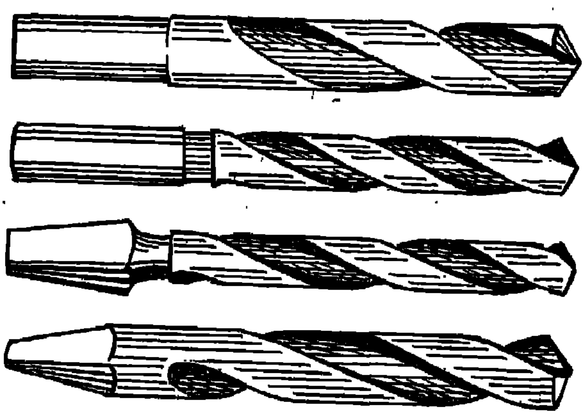


DETAILS OF A TWIST DRILL.

The Point—is the cone-shaped cutting edge; the correct angle of the cutting edges with the side of the drill is 121°, giving an included angle of 118° between the cutting edges, or 59° each side of the centre line. It is also necessary to have a lip clearance angle, usually 12° to give clearance when cutting, so that a uniform hole may be drilled.

The Body—has two helical grooves, or flutes, on opposite sides, running the full length. These are cut in the drill by special milling machines, and the shape is such that, when the drill is ground to an included angle of 118°, the cutting edges are straight. The flutes are the means by which the cuttings are automatically carried from the hole when drilling. They also provide the cutting edges at the point. The diameter of the body of the drill is lightly reduced or "backed off," except for a narrow strip, called the "land," running along the edge of the flutes. This backing off allows body or longitudinal clearance to the drill, which reduces friction and prevents the drill from gripping or "seizing" the metal. The web of the drill is the centre portion between the flutes. This increases in thickness from the point to the top end of the flutes, in order to give greater strength towards the shank when drilling.

The Shank—is that portion of a drill which is gripped by the drilling machine. There are three types of shanks,



TYPES OF TWIST DRILLS.

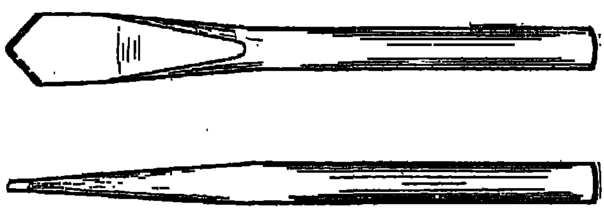
the parallel or straight, the taper and the pyramidal or tapered square. The first is usually used on drills of small diameter, the last for gripping in a brace or ratchet drill,

while the second, the taper shank, is the standard type and the one most generally used.

TAPERED SHANK TWIST DRILL.

Twist drills have the advantage of always drilling a straight hole, as the body is the same diameter as the hole being drilled. Also, it does not decrease in diameter size when ground. Accuracy in grinding these drills is essential, as undue strain on one side will cause a drill to break. When sharpening twist drills the following three points should be borne in mind :—

1. Both cutting edges should be equally inclined to the axis of the drill.
2. Both cutting edges should be the same length.
3. The clearance angle of the lips should be the same on both sides.



FLAT DRILL.

(b) **The Flat Drill**: Since the twist drill has come into universal use, it has practically superseded the flat drill, as it does the same work with far greater accuracy.

The flat drill is made from a piece of round cast steel, forged flat at one end, ground to shape, sharpened and then hardened and tempered. The angle formed by the cutting edges usually ranges from 60° to 90°, depending largely upon the thickness of the metal being drilled, the thinner the metal the more obtuse the angle. The clearance angle ranges from 3° to 12°.

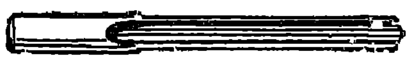
To enable this drill to do its best work, the cutting edges must be equal in length, otherwise the weight is thrown on the longer edge, resulting in an elongated hole.

This type of drill has the advantage of being cheaply and quickly made, but this appears to be outweighed by its obvious disadvantages, which are :—

(a) The body, being smaller in diameter than the cutting edges, does not assist the true running of the drill.

(b) It has no means of clearing the cuttings from the hole.

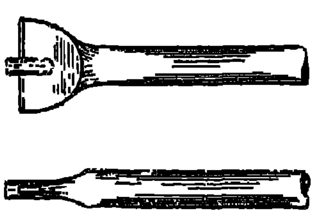
(c) The diameter of the drill is reduced every time it is sharpened. This may be overcome, to some extent, by having a short, parallel portion for about ¼ inch above the cutting edge.



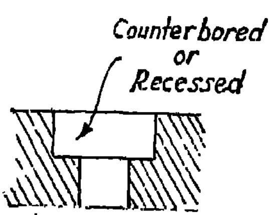
STRAIGHT FLUTED DRILL.

(c) **The Straight Fluted Drill** has *two straight* flutes, one on either side, running the whole length of the body. Its chief use is for drilling holes in brass or thin sheet metals. It has not the tendency of the twist drill to screw itself into the metal and so does not grip or bind when breaking through the underside.

(d) **The Pin Drill or Counterbore** has a straight cutting edge, divided into two by a projecting pin, the cutting

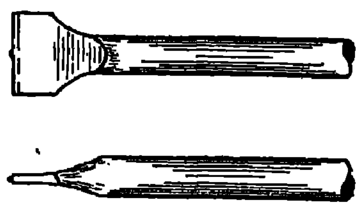


PIN DRILL.



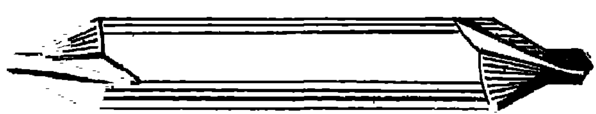
RECESSED HOLE.

edges are relieved on opposite sides and the pin should be the diameter of the hole to be recessed. The pin drill is used for counter-boring, i.e., enlarging holes to a given depth for accommodating the heads of bolts, cheese head screws, etc., and for spot facing, this latter term meaning the smoothing, on a casting, of an area around a hole in order that a washer or nut may have a more even bearing surface. The process of counter-boring consists in placing the pin in a drilled hole of the same diameter, and applying pressure until a sufficient depth of recess has been cut. During the operation the pin of the drill should be frequently lubricated.



FLAT ENDED DRILL.

(e) **The Flat-ended Drill** is very similar to the pin drill. It has a straight cutting edge with a small projection in the centre. Its main function is flattening or squaring out the bottoms of holes previously drilled with conical-pointed drills.

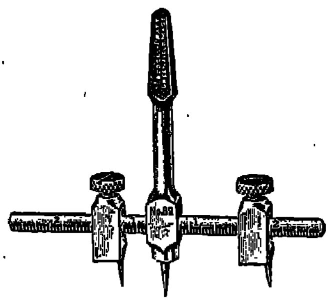


COMBINATION CENTRE DRILL.

(f) **The Centre Drill** is usually double-ended with a small straight drill running into a counter-sinking drill. It drills and counter-sinks in the one operation and is used for drilling the centres in the ends of work to be rotated in a lathe.

COUNTERSINKING DRILL.

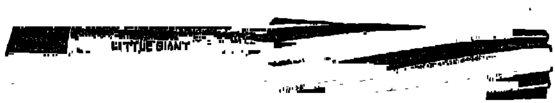
(g) **The Countersinking Drill** has several cutting edges and tapers to a point. It is used for enlarging holes to a given taper to take the heads of screws or rivets. It is also used for removing the "burr" from the surface of holes that have been punched or drilled.



WASHER CUTTER.

(h) **The Cutter Bar,** or **Washer Cutter,** has a centre rod and an arm at right angles to it. This arm carries two adjustable cutters, which are used for cutting washers or large holes in thin sheet metals.

Reamers: Drilled holes are not always perfectly round. The diameter may vary to some extent, especially when the drills are hand-sharpened. This is overcome by finishing off the holes with a reamer, which gives true accuracy. These tools are circular in section, about 6



SPIRAL FLUTED REAMER.

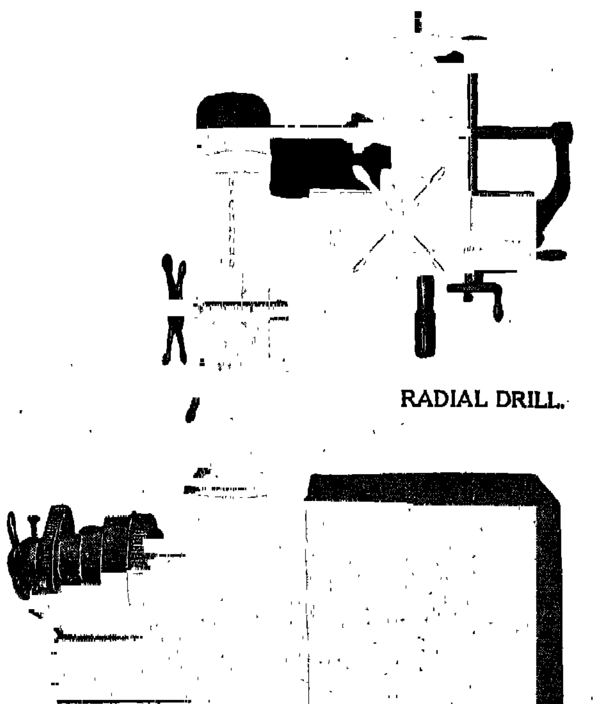
inches long, and are available in most diameter sizes. They are slightly tapered and have several flutes running along their length to provide cutting edges. Reamers are also used for giving a slight taper to a hole or for enlarging to the correct size a hole that has been drilled a little too small.

Drilling Machines: Drilling may be performed either in the lathe or by drilling machines. Drilling machines are of three kinds :—

1. *Floor Machines*, which are attached to the floor and are usually of a large nature.

2. *Bench or Wall Machines*, which usually take drills up to ½ inch in diameter.

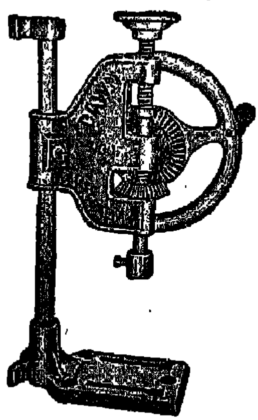
3. *Hand and Breast Drills.*



RADIAL DRILL.

1. **Floor Machines** are always power-driven. One type, the vertical column driller, has a cast-iron base with a circular pillar rising at right angles to it. This pillar carries an adjustable arm to which is attached the spindle and drilling gear. Machines of this type are to be found in nearly all engineering workshops. They are suitable for most general drilling operations and will drill holes from small sizes up to $1\frac{1}{2}$ inches in diameter.

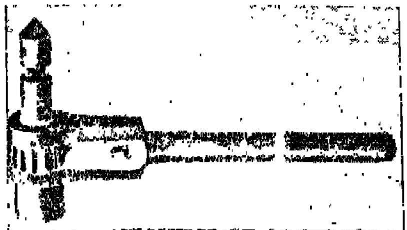
2. **Bench Machines** are screwed firmly to the bench and may be either power or hand driven. They have a cast-iron base and an upright pillar, to which is attached the adjustable arm which carries the spindle. The spindle is vertical, with a small hand wheel at the top, for applying the pressure, or feed, to the drill, and an adjustable drill chuck at the bottom for holding the drill in position. There is another short spindle, at right angles to the longer one, which has a combination hand and flywheel at one end and a bevelled gear at the other. This gear meshes with a bevelled pinion fixed to a sleeve on the centre spindle. The motive force is, therefore, transmitted



BENCH DRILL.

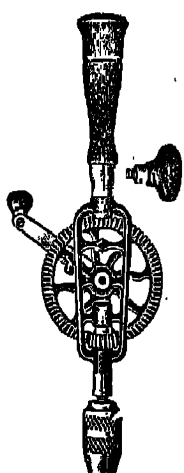
from the hand-driven wheel, through the bevelled gears to the centre spindle, which in turn rotates the chuck and consequently the drill.

Wall Machines work in a manner similar to that of the bench type, the main difference being that they are screwed, or bolted, to a wall or vertical post instead of a bench.

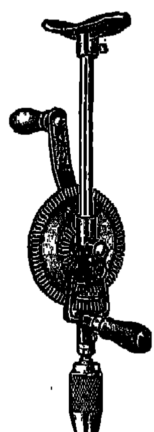


RATCHET DRILL.

3. **Hand Drills** and **Breast Drills** are used for drilling small holes. They are very convenient for drilling holes at an angle, or in work of a fixed nature that cannot be placed under an ordinary bench or floor machine. They work on much the same principle as the bench machine, except that the pressure is applied by hand, or, in the breast types that have a curved plate at the top end, by body pressure.



HAND DRILL.



BREAST DRILL.

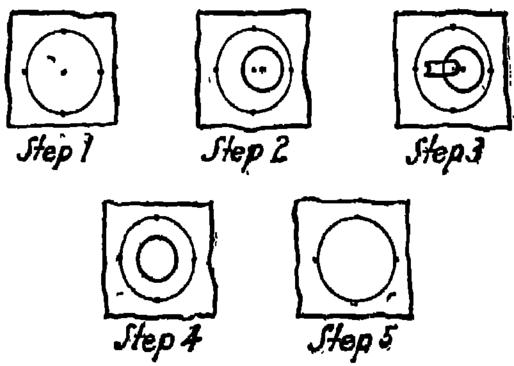
Points to be observed when drilling:

During the process of drilling there are a few points which need the special attention of the operator :—

1. The work to be drilled must be accurately " centred " and held securely so that the drill may make a true start.

2. For small holes the centre " pop " will be the only guide necessary, but this should be made large enough to receive the point of the drill.

3. For holes $\frac{3}{8}$ of an inch in diameter and over, a circle, the diameter of the hole to be drilled, should be scribed with the dividers and lightly centre-punched at four equidistant points on the circumference, these points acting as a guide for the driller.



STEPS IN "DRAWING OVER" A HOLE.

4. After the drill has entered a little distance into the hole it should be withdrawn and the work examined to see if the bore has started true. If not, it should be " drawn over," as shown, to the original centre, using either a centre punch, or a round-nose chisel, for the purpose.

5. When drilling very large holes, a small, or " pilot " hole, is first drilled through the work at the centre, to give quick cutting and to assist in keeping the centre true.

6. The feed of the drill should be even. If the "cut" is too light, time is being wasted, and, if too heavy, the drill is liable to be forced out of truth or broken.

7. The drill should be revolved at a comparatively low speed for iron and steel and at a higher speed for brass, gunmetal, etc.

The correct peripheral speed of drills for cutting metals is given in the following table :—

CUTTING SPEED (PERIPHERAL).

METAL	FEET PER MINUTE
Hard Steel	15 to 20 minimum
Soft Tool Steel	20 „ 25 „
Cast Iron	25 „ 35 „
Mild Steel	30 „ 35 „
Brass	60 „ 100 „

Note : By the peripheral speed (in feet per minute) is meant the distance (in feet) the outside edge of the drill travels in one minute.

The speed of the drill in revolutions per minute is calculated by the following formula :—

$$\text{Cutting speed} = \frac{\text{R.P.M.} \times \pi \times \text{Diameter in inches}}{12}$$

$$\therefore \text{R.P.M.} = \frac{\text{C.S.} \times 12}{\pi \times \text{Diameter in inches.}}$$

An easily remembered and approximate method is to divide 80, 110 and 180 by the diameter of the drill, the answers being the number of revolutions per minute for work on steel, cast-iron and brass respectively.

8. The cutting edges of the drill should be kept well lubricated when drilling iron or steel, otherwise they will become heated and softened, necessitating regrinding and tempering.

Lubricants: The use of some suitable lubricant serves not only to cool and lubricate the drill, but also assists in the removal of the cuttings. The following table suggests lubricants that can be used when drilling various metals :—

METAL	LUBRICANT
Hard Steel	Soluble Oil, Light Oil or Turpentine
Mild Steel	Oil (Light or Soluble) or Soda Water
Wrought Iron ...	Oil (Light or Soluble) or Soda Water
Cast Iron	Dry, or a little Kerosene
Brass	Dry, or a little Kerosene
Copper	Light or Soluble Oil
Aluminium	Kerosene, Lard Oil or Soda Water

Questions:

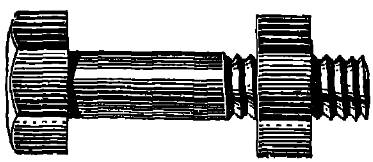
1. Of what use are drills in the engineering workshop ?
2. Name four drills and state their uses.
3. Name the main types of drilling machines.
4. Discuss three of the points to be observed when drilling.
5. Describe the method of "drawing-over" a hole that has moved off centre.

BOLTS, NUTS AND SCREWS.

Bolts, nuts and screws are usually classified under the heading of "Fastenings." They are the devices used by the engineer for holding or fastening together pieces of work or parts of machinery in their relative positions in the workshop. Their importance in mechanical work cannot be overestimated.

The following is a list of the types most frequently used in engineering practice :—

1. The Machine Bolt.	4. The Stud.
2. The Carriage Bolt.	5. Set Screws.
3. The Cap Screw.	6. Machine Screws.



MACHINE BOLT.

1. **The Machine Bolt,** sometimes referred to as a "*through*" bolt, consists of three parts—the head, body and the nut.

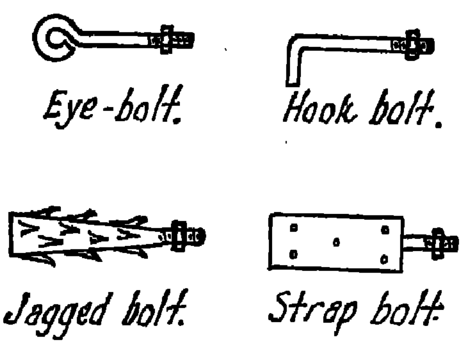
(a) *The Head*—is attached to the body and is generally square or hexagonal in shape, although for special purposes bolts can be obtained with cheese-heads. The thickness of the head is equal to the diameter of the bolt, and, in the case of hexagonal and square heads, the width across the flats is $1\frac{1}{2} \times D + \frac{1}{8}$ inch (where $D =$ the diameter of the bolt).

(b) *The Body*—is cylindrical in section with the head attached to one end. It is screwed at the other end in order to take the nut. The length of these bolts is specified by the length of the body, being measured from the end to the underside of the head.

(c) *The Nut*—is the loose or separate part of the bolt. It is attached to the body by means of a screw thread on the inside, which allows it to be screwed on to a corresponding thread on the body. The proportions of the nut are exactly similar to those of the head.

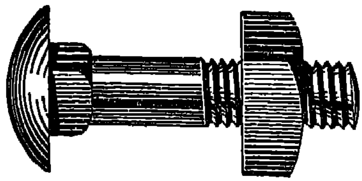
This bolt is made in two grades, a black forged type for rough work, and a bright machined type for machine construction and more accurate work. It is used where the bolt passes through the portions to be held together, pressure being applied by tightening the nut on the thread with a spanner. Frequently a washer is placed between the nut and the work to give a greater bearing surface to the nut and to prevent injury to the surface of the work. The proportions of a washer in relation to the bolt are :—

$$\left.\begin{array}{ll}\text{Diameter of washer} & = 2D \\ \text{Thickness of washer} & = \tfrac{1}{8}D\end{array}\right\} \begin{array}{c}\text{where } D = \\ \text{diameter of bolt.}\end{array}$$



TYPES OF BOLTS.

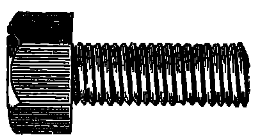
There are many types of bolts with the same proportions for nut and thread, but with differently shaped bodies each designed for a special purpose, for example, the strap, hook, jagged and eye bolts.



CARRIAGE OR CUP-HEAD BOLT.

2. **The Carriage Bolt** or **Coach Bolt**—as its name implies—is used for carriage work and coach building, as it presents a fairly smooth surface on the outside. It is similar to the machine bolt, except that the head is button- or cup-shaped (sometimes called round-headed), with a square section immediately underneath the head. This square neck is for driving into a round hole, thus squaring it and thereby preventing the bolt from turning when the nut is being tightened.

3. **The Cap Screw** has the same form and proportions as the machine bolt, except that it has no nut. It is used



CAP SCREW.

for holding parts together, when one portion, at least, of the work to be held must be threaded to provide a nut-like grip for the screw.

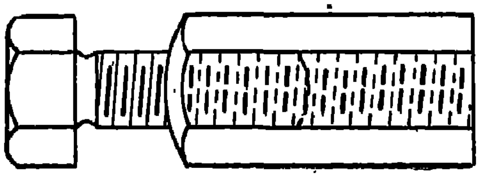
4. **The Stud**, or **Stud Bolt**, consists of a short cylindrical rod, threaded at both ends, one end being screwed tightly into a tapped hole in one portion of the work, the other end being fitted with a nut to clamp the several parts together. The stud is common where through bolts

cannot be used, *e.g.*, in the cylinder block of a motor-car and in other places where the component parts have to

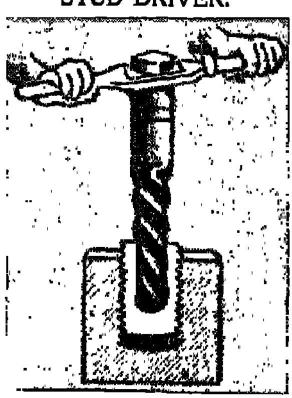
STUD.

be separated frequently. Threads tapped into cast-iron are easily injured with use, *e.g.*, with the constant removal and replacing of cap screws. This is overcome by using studs, which after being screwed into position are not interfered with, the parts being readily separated, when necessary, by simply removing the nuts from the studs.

Stud Driver: Studs are fixed in position or removed by a tool known as a *stud driver*, or *stud box*, which fits over the top end of the stud and is turned with a spanner; they can also be inserted by using two nuts, one locking



STUD DRIVER.

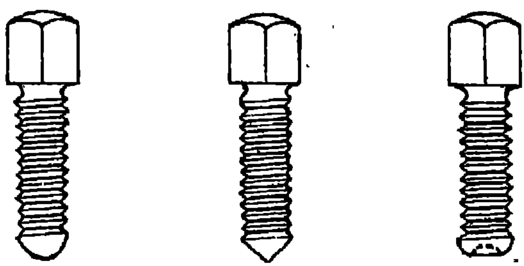


USING A STUD EXTRACTOR.

on the other. If a stud breaks off it can be removed by filing a square section on the projecting portion and then removing it with a spanner, but, if broken off level with the surface, it is necessary to drill a hole in the remaining portion and insert a stud extractor.

5. **Set Screws** are made of cast steel and tempered, or of mild steel with case-hardened points. They are usually screwed for the whole of their length with square heads and points which are either round, conical or cupped in shape. They form a convenient and widely used means

TYPES OF SET SCREWS.



Round Point. Conical Point. Cup. Point.

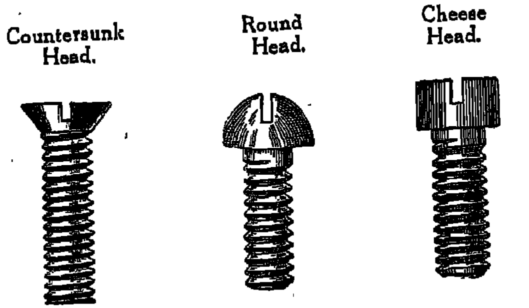
of securing pulleys, collars, handles, etc., to shafts or spindles. Set screws are not well suited to the holding of pulleys that must transmit much power; as they have only a small area in contact with the shaft and so are apt to slip.

There are also types of set screws without heads, known as headless or "safety" set screws, which are screwed in flush with the surface either by a screwdriver or a small key spanner fitting into an opening shaped to receive it.

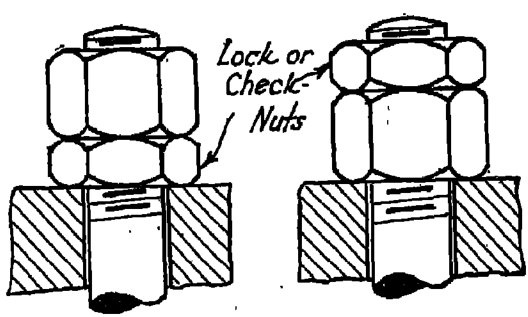
6. **Machine Screws** are the small screws used by the engineer. They are screwed for their whole length and

have slotted heads of various shapes, *e.g.*, flat (countersunk), round and cheese heads.

TYPES OF MACHINE SCREWS.



Nut Locking Devices : It is frequently necessary to lock the nuts on bolts, and studs to prevent them working loose, especially when the nuts are subjected to vibration. Some of the devices in use for this purpose are as follows :—

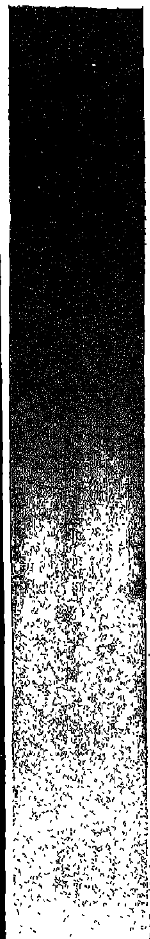


METHOD OF USING LOCK NUTS.

(a) **Lock Nut Device :** This is the most common method in use. Two nuts are used, one being of standard thickness and the other, called the lock or check nut, half the standard thickness. The standard nut is screwed down on the

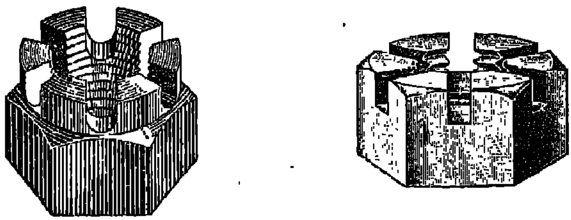
Steel Tempering Chart

CARBON TOOL STEEL



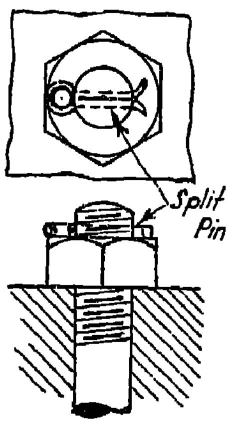
Colour	Deg. C.	Deg. F.	Uses
BLUE	300	572	Spring
PURPLE	295	563	Rules; Circular saws for metal
	290	[illegible]	Hacksaw blades; Cold chisels for wrought iron
	285	545	Files; Needles
BROWN	280	536	Cold chisels; Screwdrivers; Blades for snips
	275	527	Calipers; Hot setts
	270	[illegible]	Scribers; Augers; Flat drills for brass
	265	[illegible]	Twist drills; Plane irons
	260	[illegible]	Reamers; Gouges
DARK STRAW	255	491	Punches, dies, cups and snaps; Chasers
	250	[illegible]	Taps; Screw-cutting dies
MEDIUM STRAW	245	473	Boring cutters; Milling cutters
	240	[illegible]	Planing and slotting tools for iron
	235	[illegible]	
LIGHT STRAW	230	[illegible]	Planing and slotting tools for steel; Hammer faces and panes
	225	437	Screwing dies for brass; Light turning tools
	220	[illegible]	Scrapers and lathe tools for brass

work in the usual manner and the check nut screwed tightly on to it, with the effect that the thread is locked securely between them.



CASTLE OR SLOTTED NUTS.

(b) **Castle,** or **Castellated, Nut:** This device is used largely in motor-car work. The nut has several slots cut across the top which are used in conjunction with a split pin. The nut is tightened down on the work until one of the slots coincides with a hole in the bolt. A split



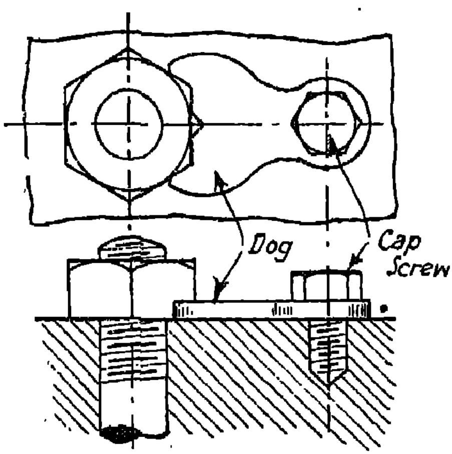
SECURING NUT WITH SPLIT PIN.

pin is then inserted and opened out on the far side, thus firmly holding the nut in position. Similar to this also is the method of using an ordinary nut with holes drilled horizontally through it and inserting a split pin through

a corresponding hole in the bolt, or again of simply inserting a split pin through a hole in the bolt immediately above the nut after it has been screwed down tight.

SPRING WASHERS.

(c) **Spring Washer:** This device is one that is very *quickly applied* and is fairly effective. The washer is split and the ends offset slightly to form a helix. When the nut is tightened on to it, this washer tends to force the nut away and, by so doing, keeps it pressed firmly against the threads, also the split ends of the washer bite into the underside of the nut and the surface of the



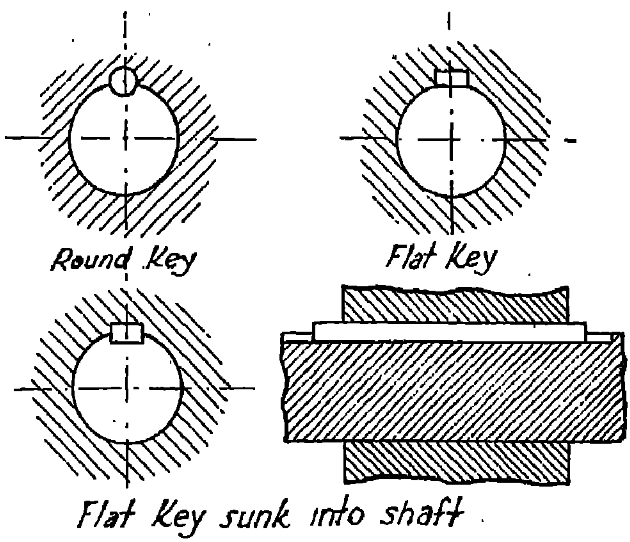
COVER WASHER DEVICE.

work, so helping to prevent the nut turning on the screw. There are several other types of washer devices in use

such as the lug and cover washers, the latter type being very useful for holding large nuts in position.

Keys and Keyways:

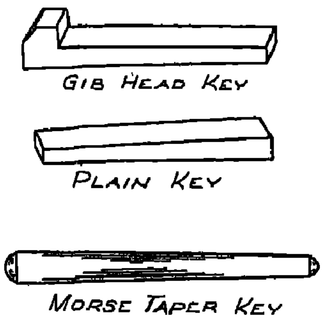
Brief mention might be made here of the methods, apart from set screws, used in machine construction, for fastening such parts as pulleys, gear wheels, etc., to



METHOD OF FITTING KEYS.

shafts. The chief method is that of using keys, the most common types being the *Flat*, *Round* and *Woodruff* keys, the first-named being most generally used. The most reliable method of using the Flat key is to sink it into the shaft. This is done by cutting a keyway, half the depth of the key and equal in width to it, into both shaft and pulley. These slots are then made to correspond and the key driven home, with the result that the pulley is effectively locked on the shaft.

The Round key is used in a somewhat similar manner. The pulley is first placed in position on the shaft and then a small hole drilled half in the shaft and half in the hub of the pulley and a round key driven firmly in to hold them in position.



TYPES OF KEYS.

The Woodruff key is used mainly by the manufacturers of machine tools and not very much in general practice.

Questions :

1. What part do bolts, nuts and screws play in engineering practice ?
2. Name two types of bolts in common use.
3. Name two types of screws in common use.
4. Describe three methods of locking nuts.
5. Which, in your opinion, is the most effective of the nut-locking devices, and why ?

STANDARD SCREW THREADS.

A great advance has been made in the design of screw threads since the time when they were originated by wrapping a right-angled triangle around a cylinder and using the hypotenuse as a guide in forming the thread with a file. Screws are now formed by cutting a helical groove, of a required shape and size, on the outside of circular rods and on the insides of circular holes.

The chief requirements in a screw thread are :—

Power.
Strength.
Durability.

Power—to draw firmly together the parts it unites.

Strength—to withstand any shocks or strains to which it may be subjected.

Durability—to withstand the wear and tear of general usage.

In relation to their uses screw threads may be divided into two classes or groups :—

(a) Those used for fastening or binding and for producing pressure between surfaces.

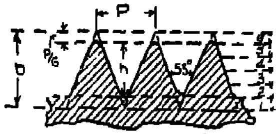
(b) Those used for transmitting or modifying motion and for adjusting the relative positions of parts.

The main types of threads covering these groups in use to-day are as follows :—

1. The Whitworth.
2. The Sellers.
3. The British Association.
4. The Square.
5. The Acme or Truncated cone.
6. The Buttress.

1. **The Whitworth Thread :** This is the *British standard " V " thread.* It is triangular in form with an included angle of 55°. It has one-sixth of the depth of the triangle

rounded off, both at the ridge and at the bottom of the groove, making the depth of the thread two-thirds that



Whitworth Thread.

of the full triangle. The isosceles triangle of 55° has a height of .96 of its base, which, being reduced by one-third, gives a depth of thread which is .64 of the pitch. The pitch of a thread being the distance it advances in making one revolution.

2. **The Sellers Thread :** is the *American standard thread.* It is very similar to the Whitworth thread, being triangular in form, but with an included angle of 60°, with one-eighth of the height of the full triangle cut off (i.e., flattened) top

Seller's Thread.

and bottom, making the depth of the thread three-quarters that of the full triangle. Therefore, the height of the equilateral (60°) triangle being .866 of its base, when reduced by one-quarter, makes the depth of the thread equal to .65 of the pitch.

In the British and American standard screws the number of threads per inch is identical, with the exception of the ½ inch diameter, which has 12 per inch in the former and 13 in the latter.

The Whitworth and Sellers threads both have the same uses in their respective countries, being used for general engineering purposes, on bolts, nuts, pipes, etc.

COMPARISON OF THREADS PER INCH.

DIAMETER OF BOLT	NUMBER OF THREADS: WHITWORTH	NUMBER OF THREADS: SELLERS
1 inch	8	8
$\frac{7}{8}$,,	9	9
$\frac{3}{4}$,,	10	10
$\frac{5}{8}$,,	11	11
$\frac{1}{2}$,,	12	13
$\frac{7}{16}$,,	14	14
$\frac{3}{8}$,,	16	16
$\frac{5}{16}$,,	18	18
$\frac{1}{4}$,,	20	20

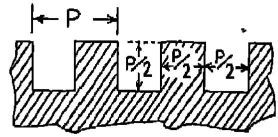
3. **The British Association Thread**—commonly referred to as the *B.A. thread*—was developed from the Thury Swiss thread. It has an included angle of $47\frac{1}{2}°$ and is rounded off two-elevenths of the pitch at both the top and bottom of the thread. This thread was devised for

British Association.

work of a small nature and is generally used in the manufacture of scientific instruments, electrical apparatus, clocks, etc. On account of its rounded form it is not so liable to injury as are the finer-edged threads.

4. **The Square Thread** is quite square in section, with the pitch taken as twice that of the Whitworth thread for equal diameters, so making the width and depth of the thread equal to half the pitch. This thread is used for transmitting motion and exerting pressure at right angles to the axis. By having the advantage of presenting a surface at right angles to the line of pressure, there is no tendency for it to slit the nut. The square

thread is used for the lead screws of lathes and in vices, cramps, etc.



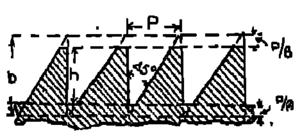
Square Thread.

5. **The Acme Thread, or Truncated Cone Thread** has an included angle of 29° with a depth of thread ($\frac{P}{2}$ + .010), where P = pitch. This thread is used for all lead screws

Acme Thread.

on lathes when the nut has to be tapped out and where the nut which engages the lead screw is in halves and engages while the screw is revolving. On account of the ease with which the half, or clasp, nuts engage this thread, it has largely superseded the square thread for lead screws.

6. **The Buttress Thread** is equal in pitch to the Whitworth thread. It has one face at right angles to the axis with the other at 45° to it. The depth of the



Buttress Thread.

thread is equal to three-quarters of the pitch with the threads flattened one-eighth of the total depth top and bottom. It is used for gun and press screws and in the "instantaneous grip" vice where the pressure has to be

taken in one direction only. In this respect, it is stronger than the square thread as it is wider at the base, and so combines the advantages of the " V " thread with those of the square for this special type of work.

SUMMARY.

Screw threads are formed externally and internally by cutting helical grooves of required shapes on the outside and inside of cylinders. They can be divided into two classes according to their uses, viz. :—

(a) Those used for fastening and for producing pressure between surfaces.

(b) Those used for transmitting motion and for adjusting the relative positions of parts.

The main types of threads covering these groups are :—

1. The Whitworth.
2. The Sellers.
3. The British Association.
4. The Square.
5. The Acme.
6. The Buttress.

1. **The Whitworth Thread**—is the British standard " V " thread. It is triangular in form with an included angle of 55°.

2. **The Sellers Thread**—is the American standard thread. It also is triangular in form with an included angle of 60°.

The Whitworth and Sellers threads are used for general purposes, such as on bolts, nuts, pipes, etc.

3. **The British Association Thread,** or B.A. Thread—has an included angle of $47\frac{1}{2}$°. It is used for small screws in the manufacture of scientific and electrical apparatus, clocks, etc.

4. **The Square Thread**—is quite square in section, the depth and width of the thread being equal to half the pitch. It is used for transmitting motion and exerting pressure at right angles to the axis and so is found on the lead screws of lathes and in vices, cramps, etc.

5. **The Acme Thread**—has an included angle of 29°. It also is used for the lead screws of lathes on account of the ease with which it engages the half nut. It has largely superseded the square thread in this respect.

6. **The Buttress Thread**—has one face at right angles to the axis and one at 45° to it. It is used in places where pressure is applied in one direction only, as in the "instantaneous grip" vice, and, for this type of work, it combines the advantages of the "V" thread with those of the square thread.

Questions:

1. How are screw threads formed?
2. What properties are required in a screw thread?
3. What are the two classes into which threads can be divided?
4. Name three common threads and state their uses.
5. Discuss the advantages, or disadvantages, of the Acme thread in comparison with the Square thread.

TAPS AND TAPPING.

Screw threads may be divided into two classes, viz. :—

(a) Internal.

(b) External.

SCREW-CUTTING.

Threads used for transmitting motion, or where great accuracy is desired, are cut in the lathe, while those used for fastening and general purposes, usually not exceeding one inch in diameter, are cut, if internal, by taps and, if external, by dies.

TAPS AND TAPPING.

Taps: These tools are used to cut internal threads or screws, as in a nut. They are made of high-grade tool steel and are tempered to a sufficient degree to cut other metals and to suit the severe nature of the work they are called upon to perform.

Taps have two parts, the body and the shank.

The Body is about two-thirds the length of the whole tap. It is screwed for its full length, with the teeth slightly backed off to allow clearance, and is fluted in order to provide the alternate edges with a cutting action and to allow the cuttings to escape.

The Shank is round in section with a milled square at the top to receive the tap wrench by means of which the tap is revolved.

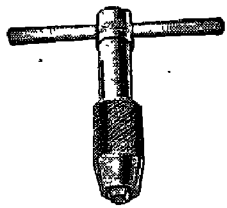
Taps are made in sets of three to each diameter size, the three comprising what is known as a tap set. Each tap set consists of :—

(a) A taper (or entry) tap.

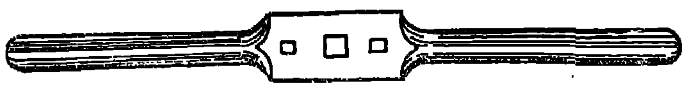
(b) An intermediate (or second) tap.

(c) A plug (or bottoming) tap.

The depth, however, should never exceed $1\frac{1}{2}$ times the diameter of the screw.



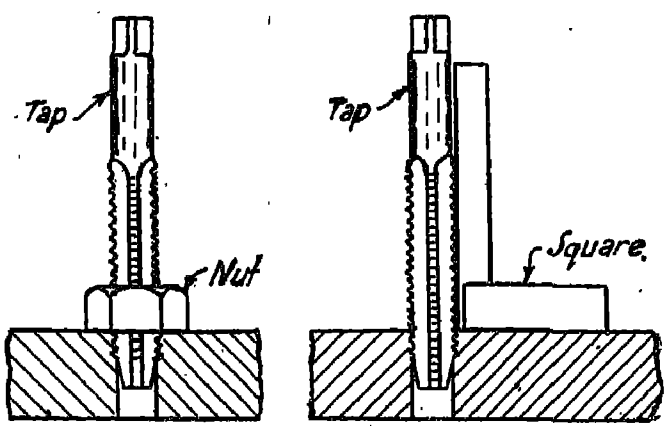
Adjustable.



Fixed.

TAP WRENCHES.

The procedure, when tapping, is to insert the taper tap into the hole and to fit a tap wrench, of a suitable size, to the squared shank for, as the tapping of holes in



METHODS OF KEEPING A TAP SQUARE.

metal requires considerable force, a tap wrench must be used to provide leverage.

The tap is revolved to the right and a downward pressure exerted to commence the thread, care being taken to see that the tap enters the hole squarely. This necessitates the frequent use of a try-square. A nut may also be used to keep the tap square, providing it is a good fit and has its bottom face square to the axis of the tap.

It is impossible, when going through the hole for the first time, to give a continuous forward movement to the tap owing to the resistance offered by the metal being cut. It is necessary, therefore, to "*humour*" the tap, i.e., when it becomes jammed it should not be forced forward, as this would cause it to break, but should be eased back a little and then screwed forward again, this process being repeated as often as may be necessary throughout the cutting of the thread.

The shank of the tap is usually smaller in diameter than the body which, in the case of a through hole, allows the tap to drop right through the work after the thread has been cut, thus avoiding the necessity of winding it all the way back.

Taps are sharpened by carefully grinding the cutting edge of the flutes. They are usually broken by applying uneven pressure to the handles of the wrench, or by using more force than is necessary to cut the thread. A broken tap can be extracted by a special pronged tool that grips the flutes. If this fails, it is usually necessary to anneal and drill it out.

Lubricants should be used freely during tapping on all metals, except brass and aluminium, as they help to preserve the cutting edges, keep the tool cool and facilitate the process.

Table of Tapping Sizes:

DIAMETER OF TAP	NUMBER OF THREADS PER INCH	DIAMETER OF TAPPING HOLE
1 inch	8	$\frac{27}{32}$ inch
$\frac{7}{8}$,,	9	$\frac{47}{64}$,,
$\frac{3}{4}$,,	10	$\frac{5}{8}$,,
$\frac{5}{8}$,,	11	$\frac{33}{64}$,,
$\frac{1}{2}$,,	12	$\frac{13}{32}$,,
$\frac{3}{8}$,,	16	$\frac{19}{64}$,,
$\frac{1}{4}$,,	20	$\frac{3}{16}$,,
$\frac{3}{16}$,,	24	$\frac{9}{64}$,,

Questions :

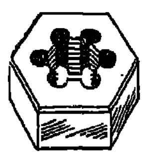
1. What are taps ?
2. Name the three taps which comprise a set.
3. Name and describe the parts of a tap.
4. State one formula used for obtaining the tapping sizes for holes.
5. Explain what is meant by "humouring" a tap.

STOCKS AND DIES.

The most common method of cutting external threads is by means of stocks and dies. These can be obtained in many different sizes and designs.

STOCK.

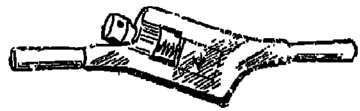
Stocks—are made of mild steel and consist of two handles secured to a frame, usually circular or rectangular in shape, into which the die is fitted and clamped. Both die socket, or recess, and the points of the adjusting and clamping screws are case-hardened to withstand wear and strain. In many of the larger types of stocks the handles are screwed into the frame and so can be removed for convenience when being replaced in the case after use.



HEXAGON DIE.

Dies—are made of the best cast steel, hardened, tempered and cooled in oil to prevent brittleness. They are provided with internal screw threads and are fluted, the flutes providing the cutting edges and clearance for the cuttings to fall away. The first two or three teeth on the advancing side of the die are chamfered off to facilitate the starting of the thread. These teeth do most of the

cutting, those following simply sizing. If it is desired to cut a full thread close up to a shoulder the die must be turned over.



STOCK WITH SLIDING HALF DIES.

For work of a larger nature dies are often made in two halves, usually rectangular in shape, with V-shaped grooves, which fit on to corresponding V-shaped projections in the frame of the stock and are adjusted by a long-threaded screw. The majority of dies to-day, however, both for large or small work, are circular in shape, and

ADJUSTABLE DIES.

the best types are fitted with devices by which they can be adjusted, within narrow limits, in order to make light or heavy cuts and to allow for wear. This is accomplished by an adjusting screw which allows the die to open or close as required.

Using the Stock and Die: In using the stock and die, the end of the blank rod to be screwed should be chamfered to give the die a better start, while the body of the rod should be cleaned with a file to remove any oxides or scale that may be on it. The die is then opened wide enough to allow it to make only a light cut on the rod. After so doing the die in the stock is revolved to the right when it will cut the light thread to the required length. The stock is then run back to the top and the die adjusted to cut the thread a little deeper. This process is repeated until the thread is sufficiently deep with clean and sharp edges.

Care must be exercised, from the start to see that the stock is held squarely, thus ensuring a straight and true thread. The die must not be forced when cutting, as this is likely not only to produce a bad thread, but also to break the teeth in the die. It should be " humoured " in exactly the same way as a tap.

Lubrication: As when tapping, a lubricant should be freely used when screwing metals such as iron, steel or copper, but is not required for brass.

SCREW PLATE.

The Screw Plate is used for cutting threads for very small screws. It consists of a thin plate of tempered steel, fitted with a handle. It has a number of threaded holes of varying diameters, two holes to each diameter size, one of the correct size and the other a little larger, with small holes on each side of the threaded holes, to provide cutting edges and clearance for the cuttings to fall away. Screw plates act as much by pressure as by cutting and are suited only for work of small diameters where absolute correctness of thread is not required.

SUMMARY.

The most common method of cutting external threads is by means of Stocks and Dies.

The Stock is made of mild steel and consists of two handles secured to a frame into which the die is fitted and clamped.

The Die is made of cast steel, hardened and tempered. It has internal screw threads and is fluted, the flutes providing the cutting edges. Dies are usually circular or rectangular in shape. The best types can be adjusted, within narrow limits, to give a light or heavy cut to the thread and to allow for wear. The first two or three threads of the die are chamfered off to enable the die to start easily.

Using the Stock and Die : The blank rod to be screwed should first of all be chamfered to facilitate the starting of the thread, which is done by revolving the die, by means of the stock, to the right.

Care must be taken to see that the stock is held squarely, thus ensuring a straight and true thread. The die must not be forced, otherwise a bad thread will be produced. As when tapping, a lubricant should be freely used on all metals with the exception of brass.

Questions :

1. What is the function of the stock and die ?
2. Describe the stock and die.
3. How is the blank rod treated before commencing to cut the thread ?
4. What precautions must be taken when cutting a thread ?
5. What is a screw plate ?

FORGING & HARDENING COLOUR CHART

TEMPERATURE FAH.	TEMPERATURE CEN.	COLOUR
1346°	730°	BLOOD RED
1382°	750°	MEDIUM CHERRY RED
1436°	780°	CHERRY RED
1517°	825°	BRIGHT CHERRY RED
1562°	850°	FULL RED
1652°	900°	BRIGHT RED
1796°	980°	YELLOW RED
1832°	1000°	ORANGE
2012°	1100°	YELLOW
2282°	1250°	WHITE
2372°	1300°	FULL WHITE

COLOURS SEEN IN SUBDUED LIGHT

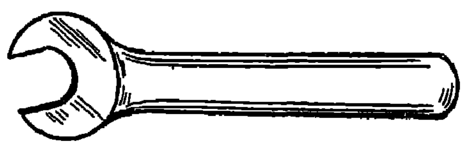
SPANNERS.

Spanners are the tools used by the engineer and metal worker for tightening and loosening the nuts on screws. They are generally made of either cast steel or mild steel and are usually shaped by the process of "drop forging." The mild steel spanners are case-hardened to give added strength and to prevent the insides of the jaws becoming "burred" or enlarged through strain.

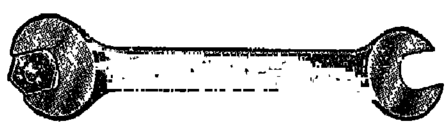
Spanners are made in various forms, for use on nuts, bolts, set screws, etc. Some of the most common types are :—

(a) Machine.	(d) Ring.
(b) Adjustable.	(e) Pin or Face.
(c) Box.	(f) Collet.

Each of these types has been specially designed to meet certain requirements, their details and uses being as follows :—



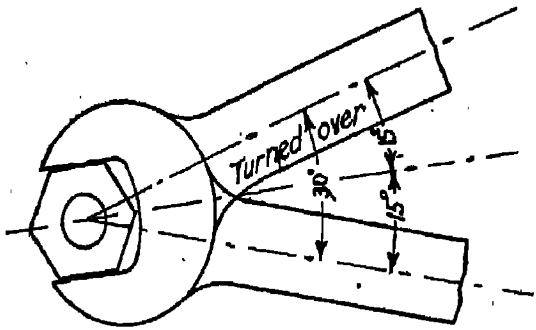
SINGLE-ENDED SPANNER.



DOUBLE-ENDED SPANNER.

(a) **Machine Spanners**—sometimes referred to as "*block*" or "*set*" spanners, are the type in general use in the engineering workshop. They are made both single and double-ended and, owing to their solid construction, are preferable when turning standard nuts.

The jaws of the machine spanners are usually set at an angle of 15 degrees to the axis of the handle for hexagonal nuts and $22\frac{1}{2}$ degrees for square nuts. The advantage

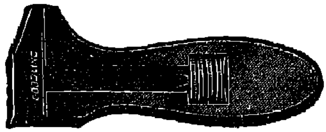


OFFSET OF SPANNER JAWS.

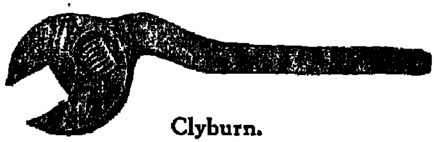
of these angles is that a nut may be turned in a confined space by reversing the spanner after every partial turn of the nut, thus allowing the maximum movement in the least possible space, as shown.

The width of the jaws corresponds with the width of the nut it is required to fit, and so is found by using the same formula as that employed for finding the distance across the flats of a nut, i.e., ($1\frac{1}{2}$D + $\frac{1}{8}$ inch) where D = diameter of bolt. Thus, a $\frac{1}{2}$-inch spanner should be $\frac{7}{8}$ inch across the jaws. It should be noted that the size stamped on the face of the spanner is not the width across the jaws, but the diameter size of the bolt, whose nut it is required to fit, so that, according to the above formula, a spanner stamped $\frac{5}{8}$ inch would be $1\frac{1}{16}$ inches across the jaws.

The length of a spanner is usually taken as 12 to 14 times the diameter of the bolt, whose nut it fits, *e.g.*, the length of a $\frac{3}{4}$-spanner would be from 9 to $10\frac{1}{2}$ inches.



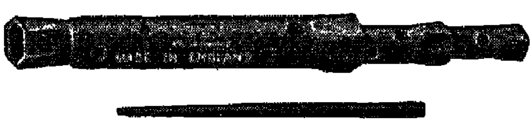
King Dick.



Clyburn.

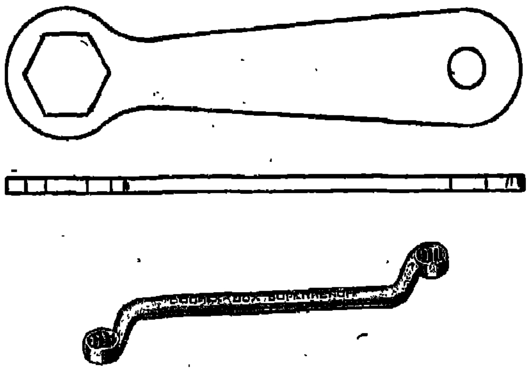
ADJUSTABLE SPANNERS.

(b) **Adjustable Spanners**—generally called "shifting" spanners, are made in many different forms and sizes, the most common types being the "King Dick" and "Clyburn." These spanners are made of mild steel, case-hardened, and serve the same purpose as the machine spanner, their great advantage over the former type being that they can be adjusted to fit various sized nuts.



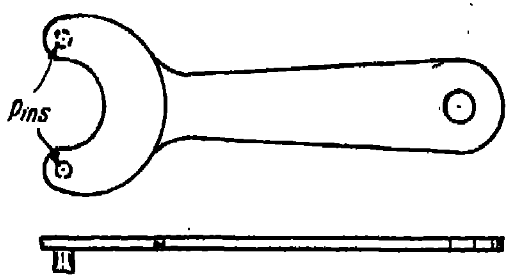
SET OF BOX SPANNERS.

(c) **Box Spanners**—are also made in varying shapes, the most common, however, is the double-ended tubular type, which has a different nut size at each end of a short cylinder, and is turned by inserting a rod through two holes in the body of the cylinder. These spanners are used for adjusting nuts, etc., which are sunk into a recess, or are in positions difficult of access. They are also very safe to use because, every side of the nut being gripped simultaneously, it is practically impossible for the spanner to slip.



RING SPANNERS.

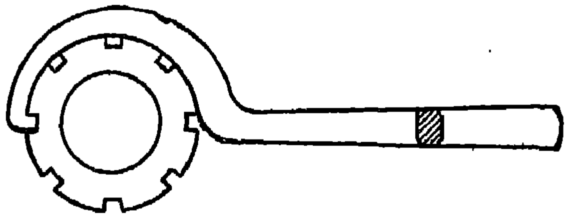
(d) **Ring Spanners**—have much the same principle as the box spanner in that they grip the six faces of an hexagonal nut at the one time. They are used for adjusting nuts, cap screws, etc., in general work.



PIN SPANNER.

(e) **Pin Spanners**—are usually flat and have two pins at one end which fit into two corresponding holes in a circular nut. They are used for adjusting circular nuts which are usually sunk into the work with the top of the nut level with the surface.

(f) **Collet Spanners**—are made in the shape of a half-circle, with a pin at one end and a straight handle at the other. They are used for adjusting circular nuts



COLLET SPANNER.

which have grooves let into their circumference and into which the pin of the spanner fits.

Using the Spanners : When using a spanner the following points should be observed :—

1. The spanner should fit tightly on the nut, otherwise it may slip, causing injury to the corners of the nut or perhaps strain the jaws of the spanner. Also it may mean possible injury to the operator.
2. When using an adjustable spanner, place the jaws on the nut with the opening facing the direction of pull. By so doing the jaws are less likely to spring or slip off the nut.
3. A quick pull or jerk when tightening or loosening a nut is often more effective than a steady sustained strain.
4. Before attempting to remove a nut which has rusted in position it should be well soaked with kerosene and oil.
5. The adjusting screw of a shifting spanner should be kept working freely by oiling when necessary.

Questions :

1. Name three spanners and state their uses.
2. Why are the jaws of some spanners set at an angle to the axis of the handle ?
3. Why are mild steel spanners case-hardened ?
4. What would be the width across the jaws of a spanner stamped $\frac{1}{4}$ inch ?
5. Name three of the points to be observed when using spanners.

FITS AND TOLERANCES.

Fits :

Definition : Fits or the *fit* of the parts may be defined as the degree of tightness or looseness between two pieces or parts that are intended to act together.

Classification of Fits (British Standard) :

It is essential that the engineer have a knowledge of fits, for in the assembling of any piece of machinery the parts must be fitted together in correct relation to each other. Some parts may need to revolve or move freely while others must be fitted so that only slight movement or no movement at all is possible. It is necessary, therefore, to classify the various fits in some way and the following list sets out the grouping and classes generally used in British engineering practice :—

Group 1.—*Clearance fits*—where there is a space between the two parts to allow for lubrication, freedom of movement and variations in temperature. The *Running fit* is the chief fit in this group.

Group 2.—*Transition fits*—are where the parts are fitted together in such a way that no appreciable movement is possible, but not so tight that they cannot be dismantled when necessary. The classifications in this group are :—

(a) *Sliding fit*—where the parts can be assembled by hand with slight pressure.

(b) *Push fit*—much the same as (a) but requiring a little more pressure in order to assemble.

Transition fits are not tight enough to transmit motion (or drive) and where this is required the use of some fastening device such as a key or set-screw is necessary to assist in this respect.

Group 3.—*Interference fits*—with these fits no movement at all is possible after assembly, the inner part being

definitely larger than that into which it fits. In increasing order of tightness, these fits are classified as :—

(a) *Driving fit*—where the inner part is forced into the outer by sledge hammer blows, or preferably by the use of a mandrel press.

(b) *Forced fit*—similar to (a) but the parts are forced together by hydraulic pressure.

(c) *Shrink fit*—where the outer part is expanded by heat and then forced on to the inner part, upon which it cools and in so doing, shrinks and grips securely.

Classification of Fits (American Standard) :

In American engineering practice fits are divided into eight classes, viz. :—

1. *Loose fit* : Where considerable freedom is permissible or necessary and where accuracy is not essential. It is used largely in textile, mining and agricultural machinery.

2. *Free fit* : Is a running fit used in work revolving at 600 r.p.m. and over. It is used in engines and dynamos, etc.

3. *Medium fit* : Is a running fit working under 600 r.p.m. Is used on more accurate machine tools and motor-car parts, also used as sliding fits.

4. *Snug fits* : Is the closest fit that can be assembled by hand and is used where the parts are not intended to move freely under load.

Note : The above four fits are referred to as interchangeable, the remaining four, by reason of their tightness, as selective.

5. *Wringing fit* : Is referred to as a metal to metal fit. It is used for keys, dowels, etc.

6. *Tight fit* : Requires light pressure to assemble. It is used for gears, etc., on shafts where the drive is assisted by a key.

7. *Medium forced fit* : Requires considerable pressure to assemble. It is used for fitting locomotive and rolling stock wheels on their axles and in generator and motor armatures, etc.

8. *Heavy forced* or *Shrink fit* : Is used where the ordinary forced fit is impracticable, *e.g.*, fitting locomotive tyres to the wheels.

Tolerances and Allowances:

Definition: **Tolerance** may be defined as the difference in size or the variation allowed between the largest and smallest permissible size of mating parts.

Tolerances or "*Limits of tolerance*" are required where extreme accuracy may be unnecessary or prove too expensive for general work. They also indicate that the machinist is allowed a slight margin of error. In the manufacture of a large number of similar parts it is not always possible to produce them to identical dimensions therefore the tolerance allows a slight variation from the standard size which will not prevent their effective functioning.

Definition: **Allowance** is the intentional difference made in the dimensions of mating parts.

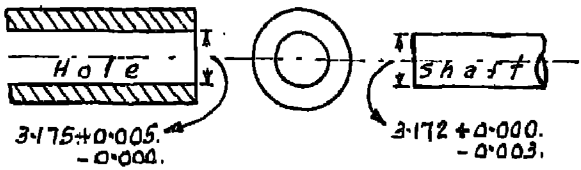
Definition: **Limit** is the extreme permissible dimension of a part.

The following table indicates the Allowances used for different classes of fits. (British Standard.)

Diameter in Inches	RUNNING FITS	PUSH FITS
Up to ½in.	—0.00075 to —0.0015	—0.00025 to —0.00075
½ " 1 "	—0.001 to —0.002	—0.0005 to —0.001
1 to 2ins.	—0.0015 to —0.0025	—0.0005 to —0.0015
2 to 3 "	—0.0015 to —0.003	—0.0005 to —0.0015
3 to 4 "	—0.002 to —0.0035	—0.00075 to —0.002
4 to 5 "	—0.0025 to —0.004	—0.00075 to —0.002
5 to 6 "	—0.0025 to —0.0045	—0.00075 to —0.002
Diameter in Inches	**DRIVING FITS**	**FORCED FITS**
Up to ½in.	+0.0004 to +0.0006	+0.0005 to +0.001
½ to 1 in.	+0.0005 to +0.001	+0.001 to +0.003
1 to 2ins.	+0.00075 to +0.002	+0.002 to +0.004
2 to 3 "	+0.0015 to +0.003	+0.003 to +0.006
3 to 4 "	+0.002 to +0.004	+0.005 to +0.008
4 to 5 "	+0.002 to +0.0045	+0.006 to +0.010
5 to 6 "	+0.003 to +0.005	+0.008 to +0.012

Note: These Allowances are for first class work only. For second and third class work multiply the allowance by 2 and 3 respectively. For extra fine work two-fifths of the allowances given are recommended.

RUNNING FIT.



Summary

	Hole	Shaft	
Tightest Fit.	3·175	3·172	= 0·003 allowance.
Loosest Fit.	3·180	3·169	= 0·011 do + tolerances.

The degree of Allowance and the formula for calculating the Allowances and Tolerances for the various American Standard fits are as follows :—

Degrees of Allowance :

1. *Loose fit*—Large allowance.

2. *Free fit*—Liberal allowance.

3. *Medium fit*—Medium allowance.

Note : With running fits the allowance is increased with the diameter but may be varied according to the length of the bearing surface.

4. *Snug fit*—Zero allowance.

5. *Wringing fit*—Zero to negative allowance.

6. *Tight fit*—Slight negative allowance, 1-4000.

7. *Medium forced fit*—Negative allowance, 1-2000.

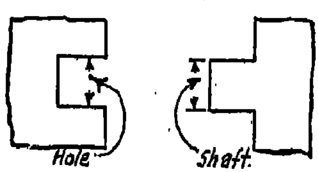
8. *Heavy forced* or *Shrink fit*—Considerable negative allowance, 1-1000.

Formulae :

Fit	Method of Assembly	Allowance	Hole Tolerance	Shaft Tolerance
1. Loose	Inter-changeable	$+0.0025\sqrt[3]{d^2}$	$+0.0025\sqrt[3]{d}$	$-0.0025\sqrt[3]{d}$
2. Free	Inter-changeable	$+0.0014\sqrt[3]{d^2}$	$+0.0013\sqrt[3]{d}$	$-0.0013\sqrt[3]{d}$
3. Medium	Inter-changeable	$+0.0009\sqrt[3]{d^2}$	$+0.0008\sqrt[3]{d}$	$-0.0008\sqrt[3]{d}$
4. Snug	Inter-changeable	0.0000	$+0.0006\sqrt[3]{d}$	$-0.0004\sqrt[3]{d}$
5. Wringing	Selective	0.0000	$+0.0006\sqrt[3]{d}$	$+0.0004\sqrt[3]{d}$
6. Tight	Selective	$-0.0025\,d$	$0.0006\sqrt[3]{d}$	$0.0006\sqrt[3]{d}$
7. Medium Forced	Selective	$-0.0005\,d$	$0.0006\sqrt[3]{d}$	$0.0006\sqrt[3]{d}$
8. Heavy Forced (Shrink)	Selective	$-0.001\,d$	$0.0006\sqrt[3]{d}$	$0.0006\sqrt[3]{d}$

Where d = Mean diameter of fit in inches.

DRIVING FIT.



0·7500 +0·0005
−0·0000

0·7500 +0·0003
−0·0000.

Summary.

	Hole	Shaft.
Tightest Fit:	0·7500.	0·7503.
	=0·0003.	
Loosest Fit:	0·7505	0·7500
	=0·0005.	

Methods of Indicating Tolerances :

Tolerances are indicated by first stating the Basic size (*or Nominal dimension*), followed by the permissible

maximum and minimum variations from it, *e.g.* :—

(a) *Shaft.* $1.624 \begin{smallmatrix} + 0.000 \\ - 0.001 \end{smallmatrix}$ *Hole.* $1.625 \begin{smallmatrix} + 0.001 \\ - 0.000 \end{smallmatrix}$

This indicates a tolerance of 0.001 on each part.
Greatest possible tightness
$(1.625 - 0.000) - (1.624 + 0.000) = 0.001.$

Greatest possible looseness
$(1.625 + 0.001) - (1.624 - 0.001)$
$\therefore = 1.626 - 1.623 = 0.003.$

Thus the clearance with the greatest possible tightness is 0.001, and that with the greatest possible looseness 0.003.

(b) 1.625 ± 0.001

In this case the Basic size (*Nominal dimension*) is shown with the one tolerance given as both plus and minus.

$$\text{Tolerance} = 1.625 + 0.001 = 1.626$$
$$\text{,,} \quad 1.625 - 0.001 = 1.624$$

Therefore the finished dimension may be either 1.626 or 1.624, or lie between the two.

(c) $1.625 \begin{smallmatrix} + 0.003 \\ + 0.000 \end{smallmatrix}$

In this case the basic size is shown with a plus tolerance only.

$$\text{Tolerance} = 1.625 + 0.003 = 1.628.$$

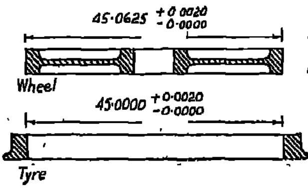
Therefore the finished dimension may range from 1.625 to 1.628.

(d) $1.625 \begin{smallmatrix} - 0.000 \\ - 0.003 \end{smallmatrix}$

In this case the basic size has a minus tolerance only.

$$\text{Tolerance} = 1.625 - 0.003 = 1.622.$$

Therefore the finished dimension may range between 1.622 and 1.625.



Summary

Tightest Fit {Wheel: 45·0625 + 0·0020 = 45·0645
Tyre : 45·0000 − 0·0000 = 45·0000
= 0·0645

Loosest Fit {Wheel: 45·0625 − 0·0000 = 45·0625
Tyre : 45·0000 + 0·0020 = 45·0020
= 0·0605

Questions :

1. Define the term "Fit" or the fit of the parts.
2. State the three groups of British standard fits and name *one* fit from each group.
3. Name *four* of the fits in the American standard classification.
4. What do you understand by the term "Tolerance"?
5. Define the term "Allowance."

LATHES AND LATHE WORK.

The Lathe is the most useful of all machine tools. It is used chiefly for shaping pieces of material by rotating them so that a cutting tool can be applied to their surface. Usually this tool is held in a fixed position as the material rotates, hence the form given by the cut is circular. It is possible, however, for the lathe and lathe tools to be so adjusted that they will carry out many more mechanical operations than that of cutting circular shapes.

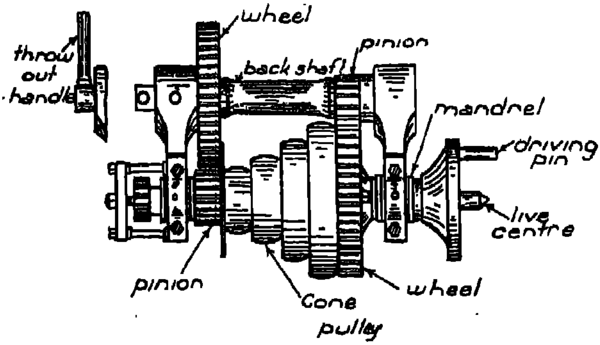
Construction of the Lathe : The lathe primarily consists of four elements :—

(a) The Bed—this is supported by standards, or legs, and carries :—
- (b) The Headstock.
- (c) The Tailstock.
- (d) The Carriage or Saddle.

(a) **The Bed :** Is invariably made of cast-iron and should be well-designed, heavy and rigid. It is the foundation upon which the other parts operate, by being either fixed to the bed or sliding along accurately planed shears or ways. These shears or ways run the full length of the lathe bed, and are made in a variety of forms; some are flat on the surface; others have inverted "V"-shaped projections on either one, or both, surfaces and which fit into corresponding "V" grooves in the attached parts. The Headstock and Tailstock rest on the inner portion of the shears and the carriage on the outer. The bed of the lathe is supported by standards or legs, attached to its under side.

(b) **The Headstock :** This contains the mechanism that receives and transmits the power through the spindle to the work. Its important parts are the retaining head, spindle, cone and the back and feed screw gearing. The retaining head should be so designed that it will resist

the heavy strains to which it is subjected. It should fit properly on to the inner portion of the shears and be securely clamped in place.



PLAN OF HEAD STOCK (SHOWING BACK GEAR).

The "live" Spindle, or *Mandrel*, and spindle bearings are very important parts of the lathe, as the accuracy of the work produced depends largely upon the true running of the spindle. In most modern lathes the spindle is hollow, having the advantage of allowing long rods or bars to be worked much more conveniently by passing them through it. The mandrel has a screwed portion which projects a couple of inches through the retaining head, towards the tailstock, for the purpose of screwing on the chuck or face plate, and it is into this portion of the hollow spindle that the "live" centre is fitted.

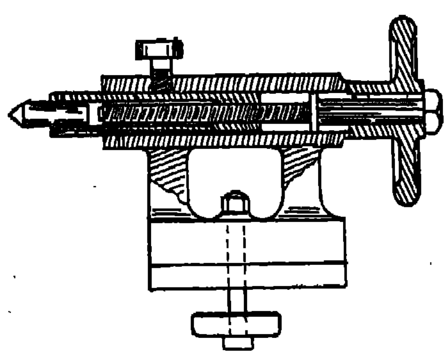
The cone or mandrel pulley is stepped in order to provide different speeds, *e.g.*, with a four-step pulley, four changes of speed can be had, the speed reducing and the leverage increasing as the driving belt is shifted from the smaller to the higher steps. The mandrel pulley works in conjunction with the driving, or counter, pulley which is attached to the main driving or countershaft, the two being connected by the driving belt.

Changes of speed are also effected by the back gearing, the purpose of this being to reduce the speed of the spindle

and correspondingly to increase its pull. This gear consists of a large and a small cogwheel (wheel and pinion respectively) fitted on to the mandrel and which mesh, when required, with two corresponding cogwheels carried on the "back-shaft," which is a small shaft running parallel with, and at the same level as, the mandrel spindle, itself. The reduction in speeds, due to back-gearing, depends on the relative proportions of the wheels and pinions, the usual ratios giving a reduction of between one-sixth and one-ninth of the ungeared speed.

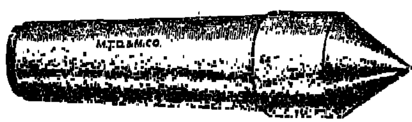
The Lead Screw of the lathe, which controls the tool feed, is connected to the mandrel by a system of interchangeable cogwheels (change-wheels) working from, and between, the ends of each. As with the back gear, the speed of the screw, and consequently of the feed, depends entirely upon the ratio existing between the gear wheels; *e.g.*, if the gear wheel on the mandrel is twice the size of that on the lead screw, then the screw will make two turns to every one of the mandrel, and *vice versa.*

In most small lathes the movements of the carriage and slide rest are effected by means of the lead screw, but, on larger lathes, these movements are effected by an additional feed rod or spindle, running parallel with the lead screw, the function of which is to relieve the screw of all feed movements other than screw-cutting and thereby prolong its life of accuracy for this purpose.



TAIL STOCK.

(c) **The Tailstock:** is carried on the bed and is accurately fitted to the shears. It is designed so that it can be moved along the shears and clamped firmly to them at any point. The function of the tailstock is to carry the spindle into which is fitted the tail or "dead" centre. This spindle can be moved in or out by turning a hand wheel at the back end, and may be locked in any position. The axis of the "dead" centre must coincide with that of the "live" centre. The tailstock is usually fitted with a cross adjustment which allows the centre to be "set over" for external tapers as well as for making any adjustment necessary to bring the centre exactly into line for parallel turning.



LATHE CENTRE.

Lathe "Centres": The lathe "Centres" are two in number and are made of hardened steel, pointed at one end to receive the work, and tapered at the other to fit securely and accurately into their respective spindles. The centre in the mandrel headstock, which is used in conjunction with the faceplate, is known as the "running" or "live" centre. The one in the tail-stock remains stationary and is called the "dead" centre.

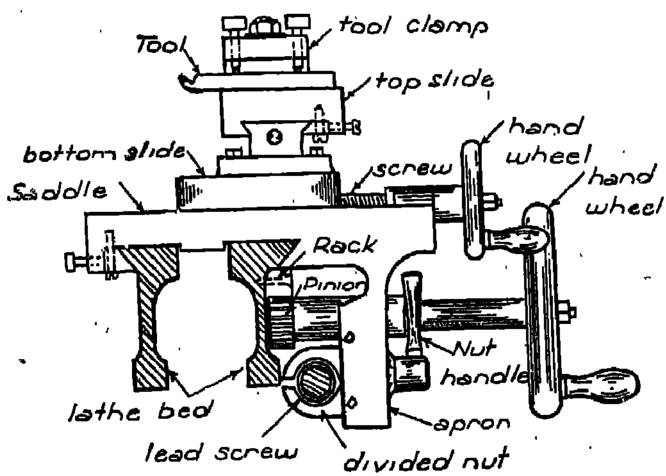
(d) **The Carriage,** or "*Saddle,*" is the tool carrying device and stands next in importance to the headstock. It rides on the outer shears of the bed and is moved over them by means of the lead screw and its connections, working through the apron.

The Lead Screw is the long screw which runs the full length of the lathe bed and parallel with it, the rotation of which is effected from the mandrel by means of cog-wheels, as explained above. The function of this screw is to convey the carriage, and consequently the slide rest, automatically along the bed of the lathe.

The Apron—is secured to the front of the carriage and passes in front of the lead screw. It contains the

mechanism through which the feed motion is transmitted from the lead screw to the carriage. Two half, or clasp, nuts are secured to the inside of the apron and are so arranged that they can be engaged with, and disengaged from, the lead screw by moving a handle on the outside. When the lead screw is in motion the carriage is moved along the bed by engaging the nuts with it; and by disengaging them the movement is arrested, although the lead screw continues in motion. When the operator wishes to move the carriage by hand, as, for example, when beginning a new cut, he must resort to the use of the Rack and Pinion.

The Rack and Pinion—are for the purpose of traversing the carriage along the bed independent of the lead screw. The rack is a bar running along the front of the lathe bed, on the underside, and has teeth for the whole of its length. It works in conjunction with a small cogwheel or pinion which is fixed to the inside of the apron, this pinion being controlled by a small spindle and handle attached to the front of the apron.



CARRIAGE OR SADDLE
(Including Slide, Rest and Tool Clamp.)

The Slide Rest consists of three main parts: the bottom slide, top slide and tool holder.

The Bottom Slide—has its underside fixed to the carriage of the lathe. It provides movement to and fro across the carriage at right angles to the bed or, in other words, it controls the surfacing or feed movements. It is adjusted by a small handwheel on the outside of the carriage.

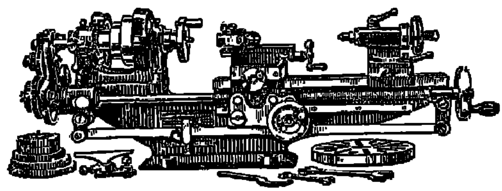
The Top Slide: The whole of the top slide is carried on the bottom slide, to which it is similar in construction. It provides the traversing motion, i.e., it travels to and fro in the direction of the length of the bed, being controlled by a small handle at the end of the slide. In some lathes the top slide is fitted with a swivel device whereby it can be adjusted, for taper turning, to any desired angle.

The Tool Clamp: Tool clamps are made in various forms, the most common types being the buckles, or bar clamps, and the post types. The former consists of two short bars fitting over four bolts, two to each, on which are placed springs to support the bars, the tool being held in position at any angle by clamping the buckles on to it by means of nuts. The post type of clamp has the tool passing through it at right angles to its axis; the tool may be set at any angle to the work, and is held securely in position by a screw adjusted from the top of the post.

Using the Slide Rest: The procedure, when using the slide rest in automatic feed, is as follows: Assuming the material to be correctly placed between the centres and the work to be done is a piece of parallel turning, the cutting tool is fixed in the tool holder and the rest run back by means of the rack and pinion to that end of the work nearest the tailstock. The tool is then adjusted close to the work by means of the top slide and set to take a suitable depth of cut by adjusting the bottom slide. The half nuts are engaged with the lead screw, which causes the tool to be automatically conveyed along the work at a steady, uniform rate, making a perfectly parallel cut. When the cut has been made, the tool is arrested by disengaging the nut from the lead screw.

If further cuts are to be made, the slide rest is run back to its former position at the tailstock end and the foregoing process repeated.

Some modern lathes are fitted with a reversing gear which, when thrown into action, causes the lead screw to revolve in the opposite direction to normal, thus causing

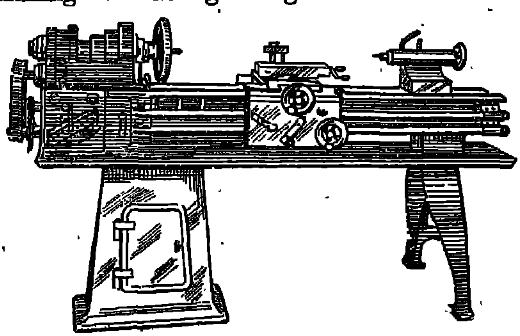


BENCH LATHE.

the carriage to move towards the tailstock. It is possible when convenient, therefore, to take a cut in either direction with a consequent saving of time and adjustment.

The slide rest can also be used for turning work, without the aid of the lead screw, by working the traversing motion by hand. Three common forms of turning that can be done by hand are :—

(a) Turning work parallel to its longitudinal axis.
(b) Turning work with a curved longitudinal outline.
(c) Making cuts at right angles to the axis.



HIGH SPEED FLOOR LATHE.

Care must be exercised when turning by hand to make sure that the cut is not too deep and that a uniform traversing pressure is maintained throughout.

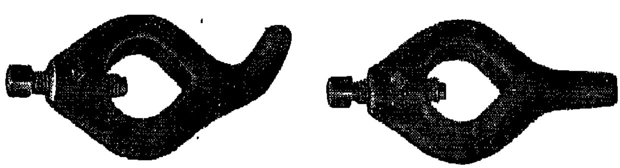
Lathe Accessories :

Under this head might be included all those tools which, while not actually part of the lathe itself, are attached to it or assist materially in the general production of work on the lathe. Some of these are :—

(a) The Face Plate.
(b) The Lathe Carrier.
(c) The Chucks.
(d) The Calipers.
(e) The "V" Blocks.
(f) The Centre Square.
(g) The Combination Centre Drill.

The latter four have already been set out under the headings of "Marking off, Measuring and Testing Tools" and "Drills," leaving the first three to be dealt with here.

(a) **The Face-Plate** : There are many ways of holding work at the headstock end of the lathe, the most common being by means of the Face-plate. This is a circular metal disc into which numerous slots and/or holes have been cast and through which the work to be turned can be secured. It is screwed onto the mandrel nose and revolves with it. The Face-plate also works in conjunction with the carrier for turning work that is supported by the lathe centres at both ends, in which case it has a driving pin projected from the face which forces the carrier around.

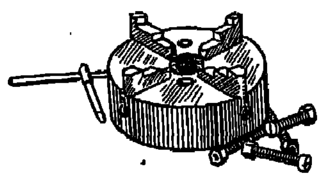


LATHE "DOGS" OR CARRIERS.

(b) **The Lathe Carrier :** This tool is usually made of cast-iron or mild steel. It is heart-shaped on the inside of a strong circular frame and is made in sizes to accommodate bars of varying diameters. At one end is

a long set-screw which tightens on to the work and securely binds it in position, and at the other end is a projection called the tail, which presses against the driving pin of the face-plate and is turned by it. Special carriers are also designed for holding work of an angular nature.

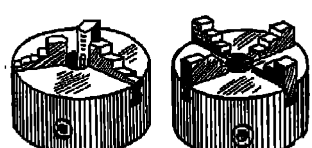
(c) **The Chuck**: Lathe chucks are screwed onto the projecting end, or nose, of the "live" spindle and provide a means of holding work more firmly and adjusting it more accurately than is conveniently possible with the face-plate. They are used for holding work when turning, etc., either in conjunction with the dead centre or independently of it. Chucks are usually classified under two headings, Independent and Self-centering.



INDEPENDENT CHUCK.

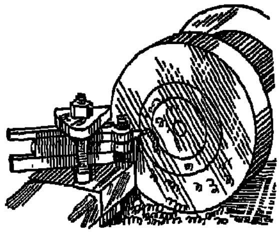
The Independent Chuck: These chucks are made with either two, three or four reversible jaws spaced evenly around the circumference, each jaw being operated independently by a square-threaded screw adjusted by a screw or chuck key. The jaws are stepped in order to accommodate work of varying diameters either external or internal.

The Self-centering, or *Universal Chuck*, usually has three or four jaws. It is similar in form to the independent chuck, except that, by turning any one of the screws with the chuck key, all the jaws move radially together, thus facilitating quick and easy adjustment of the work. There are also some smaller types of self-centering chucks



SELF-CENTERING CHUCKS.

which are frequently used for holding drills, or taps, when doing finer work in the lathe. These are known as "drill chucks," and are much similar to the types used on drilling machines.



MAGNETIC CHUCK.

LATHE TOOLS.

The chief tools used in the power-driven lathe for reducing, shaping or finishing the surfaces of metals may be set out as follows :—

(a) Roughing tools, for brass, cast-iron or mild steel.
(b) Finishing tools.
(c) Knife tools.
(d) Parting tools.
(e) Spring-finishing tools.
(f) Boring tools.
(g) Screw-cutting tools.

These tools are generally forged from the best cast steel, hardened and tempered to a light straw colour, or from speed or self-hardening steels, which retain their cutting edges even when quite hot.

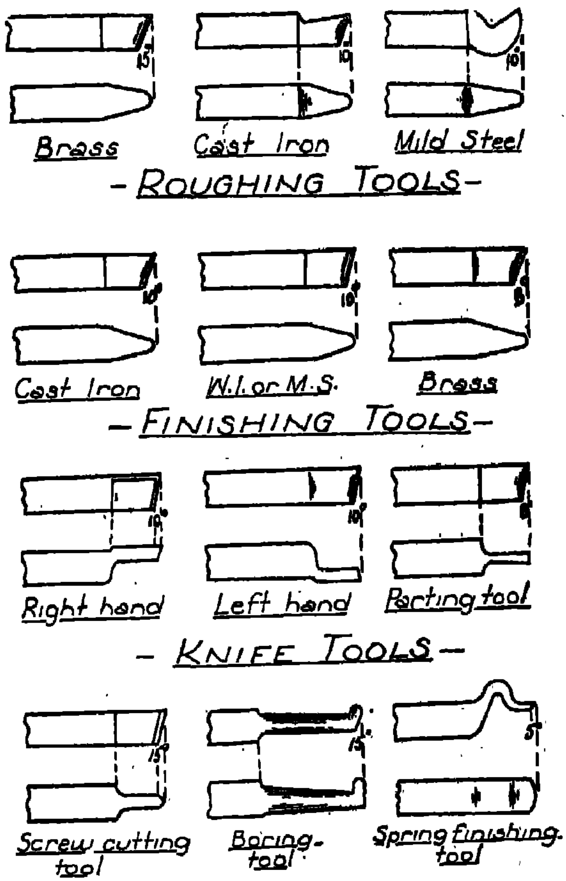
The uses and characteristics of the above tools are as follows :—

(a) *Roughing Tools*: These are made either straight, for parallel work, or bent to the right or left for side roughing, being called right- or left-hand roughing tools respectively. They are the tools used for making the first and heaviest cuts in the reduction of a surface, and have different clearance angles for cutting various metals.

(b) *Finishing Tools*—are the tools that follow the roughing tools. They reduce the metal to its finished

dimensions and give it a smooth surface. They also are set at different angles for finishing various metals.

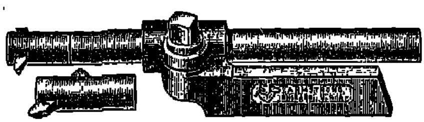
(c) *Knife Tools*—are made right- and left-handed to follow on and finish the cuts made by the side-roughing tools. They are also used for facing ends and producing sharp corners.

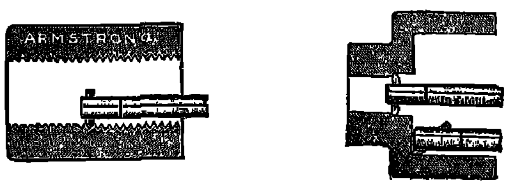


- TYPES OF LATHE TOOLS

(d) *Parting Tools*—have a narrow cutting edge and taper back from the edge to provide clearance as the tool cuts into the work. As their name implies, they are used for parting, i.e., cutting-off work in the lathe. They are also used for producing straight-sided grooves in circular work.

(e) *Spring-finishing Tools*: These tools work best on cast-iron and brass and are not suited to the production of accurate work. The spring form is given to them so that they will yield slightly rather than dig into and roughen-up the surface of the metal.





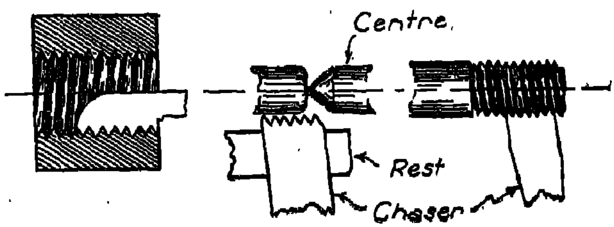
USE OF BORING BAR.

(f) *Boring Tools*—are used for cleaning out and smoothing cored holes in castings, etc., and for preparing holes prior to cutting internal screw threads. The diameter and length of the stem depend upon the diameter and depth of the bore for which the tool is to be used. This tool is necessarily a springy one and should, therefore, be as short and heavy as possible.

(g) *Screw-cutting Tools*: These tools are used for the cutting of external and internal screw threads. The cutting edges are sharpened to the correct angle and shape of the thread required. For example, when cutting a

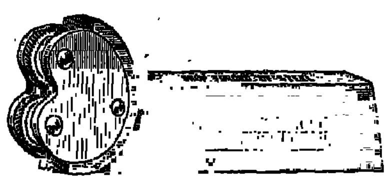
Whitworth "V" thread the cutting edge is sharpened to an angle of 55°, this angle being set or tested by means of a standard screw-cutting or centre gauge.

Screw Chasers—are used in the lathe for cutting internal and external screw threads by pressing them into the metal. Chasers are more satisfactory, however, for finishing off

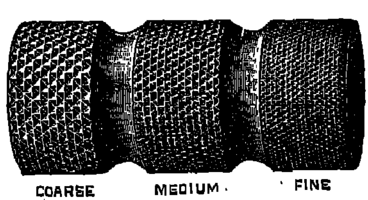


USE OF THE CHASERS.

threads after they have been cut by the ordinary screw-cutting method, or for reshaping threads that have been damaged.



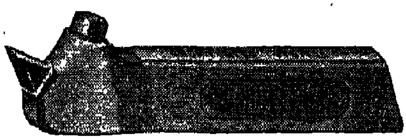
KNURLING TOOL.



EXAMPLES OF KNURLING.

The Knurling Tools—is a lathe tool in which small knurling mills of different designs are mounted upon pivots in a head which revolves in a holder. These tools are used for cutting or impressing designs on the periphery of circular work.

Tool Holders: These have largely superseded the use of solid tools. Small tools made of high-speed or self-hardening steels are fitted into these holders and firmly secured in position by a set-screw. Tool holders are made right- and left-handed and have many advantages over the solid type. For example, the small tools can be removed and kept in condition by simply grinding them to shape, instead of forging. As the tools are much smaller than the solid types, considerable material is saved, reducing their cost, therefore a better quality of steel can be afforded.



TOOL HOLDER.

"Tipping" of Machine Tools: Owing to the high cost of the special alloy metals, such as Cemented Carbides, Stellite, etc., used to-day as cutting tools it is more economical to employ small pieces or "tips." These tips may be fitted into a tool holder or supported by a solid piece of carbon steel or mild steel. When this latter method is used the tip is either wedged or brazed into a recess cut into the supporting shank, the latter being the more secure and the method most generally used.

When brazing the tip into position the procedure adopted is:—

First cut the recess in the shank to accommodate the tip and insert a small strip of thin copper into this recess between the bottom of the tip and the shank, placing a

little borax along the joint to act as a flux. The whole is then heated either in a furnace or with a blowlamp, to a temperature sufficient to melt the copper, which metal will then "flush" and firmly cement the tip to the supporting metal. After cooling the tip may be ground to the desired shape.

LATHE WORK.

Although very many mechanical operations can be carried out on a lathe, the most common functions it performs are :—

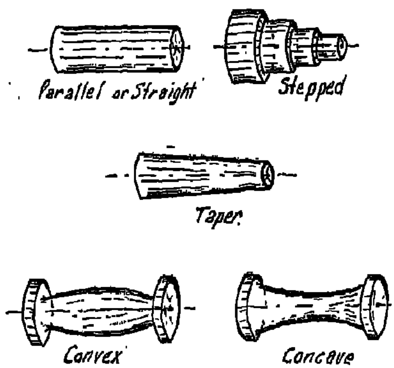
(a) Plain or Parallel turning.
(b) Convex and Concave turning.
(c) Taper turning.
(d) Facing or surfacing.
(e) Drilling and boring.
(f) Screw-cutting.

(a) **Parallel Turning** takes place when the outside surface of the work is to be turned to a line parallel with the axis. For this type of turning the tool is set at right angles to the axis of the work, the bottom slide of the slide rest being used to supply the necessary amount of cut and the top slide to traverse the tool along the work. The tools used for this type are the roughing tool, for removing the metal almost to the correct diameter, and the finishing tool, for removing the remainder and finishing-off the surface.

Stepped Turning—occurs when the surfaces are parallel to the axis but the diameters are gradually reduced in the one length. In turning this type, the straight roughing tool would be used for the parallel portions of the varying diameters and the side roughing tool for the shoulders. The parallel surfaces would be finished off with the finishing tool and the shoulders squared and finished with the right, or left-handed, knife tools as required.

(b) **Convex and Concave Turning** is the turning of work with a curved longitudinal outline. To effect this type of turning the handles of both top and bottom slides must be manipulated at the same time, the proper move-

ment of each, to produce the desired curve, depending entirely upon the skill of the operator. The tools used in this case would be the straight roughing and finishing tools.



TYPES OF TURNING.

(c) **Taper Turning :** Most lathes are fitted with either one or two conveniences for this type of turning. These are :—

(1) Setting the tool in the top slide to the required angle, so causing it to travel obliquely along the work.

(2) Setting the work obliquely to the axis of the lathe bed ; this is effected by setting the back centre out of alignment, so that the tool, travelling in a line parallel to the original axis of the centres, cuts the required taper.

(d) **Facing or Surfacing :** For facing work at right angles to the axis it is convenient to hold it in the chuck. The top slide is used for applying the "cut" and the bottom slide for carrying the tool across the work. The tools used for this purpose are the knife tools.

(e) **Drilling in the Lathe :** There are two main methods of drilling work commonly used in the lathe. These are :—

1. Where the work is held in the chuck and is revolved thereby. The drill, being fitted into the spindle of the tailstock in place of the "dead" centre, is stationary and is fed into the revolving work by operating the hand-wheel of the tailstock.

2. Where the drill is held in the lathe chuck, or in a special drill chuck, and revolves with it, the work being securely clamped to the saddle or carriage of the lathe and so moved towards the drill. **Boring:** When boring is done on the lathe, the hole must be first drilled or cast in the work and be sufficiently large to allow the boring tool to enter it. By the use of the boring tool holes that are parallel, stepped or tapered in form can be cleaned out or enlarged.

(f) **Screw-Cutting:** This function is performed in the lathe either by using tools which correspond in shape to that of the thread to be cut or by screwchasers. The former method is the one most generally used. To cut threads on metals the action of the lathe is similar to the action for parallel turning, except that, by change wheels fitted on to, and between, the back ends of the mandrel and the lead screw, the tool is made to move along the work at a speed sufficient to give the necessary pitch to the thread being cut.

Speed of Work.

The rate of cutting in the lathe varies with the metal being worked. For instance, brass and gunmetal may be cut at a faster rate than iron or steel. The rate of revolutions must also vary according to the diameter of the work in hand, *e.g.*, a large diameter travels a greater distance, in one revolution, than does a smaller one, and therefore travels at a faster speed, thus necessitating a reduction in the rate of revolutions if the peripheral speed is to be reduced.

The following table gives approximate speeds for certain metals with diameters of one inch, calculated by the following formula :—

$$C.S. = \frac{D \times \pi \times R.P.M.}{12} \quad \begin{cases} \text{Where C.S.} = \text{Cutting speed, in feet per minute.} \\ \text{,, D} = \text{Diam. of metal in inches.} \\ \text{,, R.P.M.} = \text{Revolutions per minute.} \end{cases}$$

METAL	CUTTING SPEED feet per minute	LATHE REVOLUTIONS per minute
Cast Iron	25 to 35	95 to 135
Wrought Iron ...	35 ,, 40	135 ,, 150
Bronze	45 ,, 60	170 ,, 230
Brass	80 ,, 100	300 ,, 380

If the work is run too fast over the tool there is a tendency to tear the surface of the work or to break or overheat the tool, thus softening the metal of the latter and spoiling the temper of its cutting edge.

Filing and Polishing Turned Work.

In order to remove any tool marks from the surface of the work and to give it a finish, it is sometimes filed while revolving in the lathe. The filing should be steady and evenly distributed over the work to preserve the parallelism. The strokes should cross and re-cross one another obliquely to avoid leaving file marks. A "safe edge" file should be used when filing against a shoulder.

After being filed, the work should be rubbed over with several grades of emery cloth, then with emery cloth and oil and finally, with a piece of dry, well-worn emery cloth of the finest nature to give a lustrous finish to the surface.

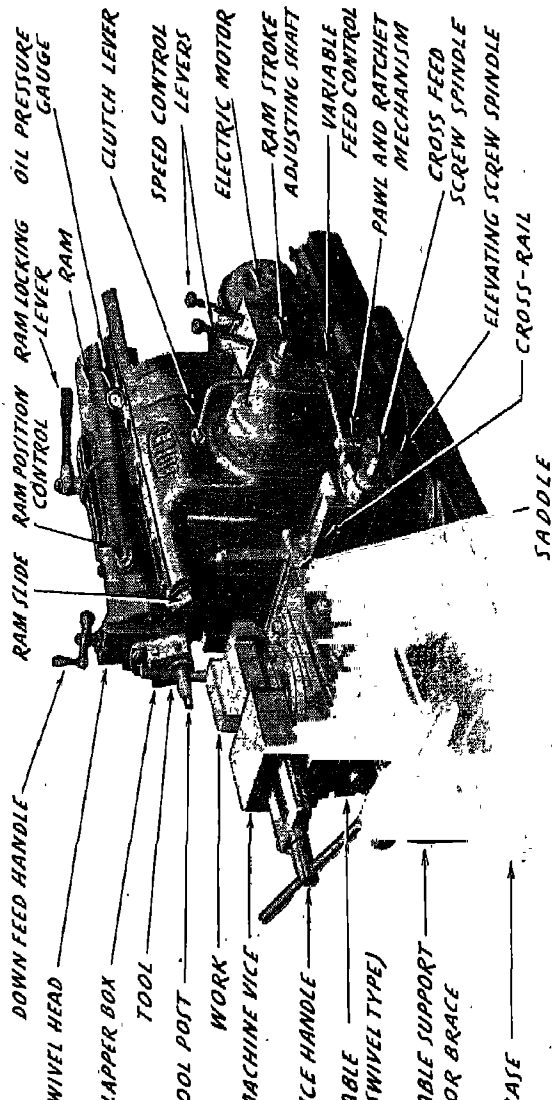
Lubrication: To secure smooth cutting and to reduce the heat caused by the friction between the tool and the work during the turning process, constant lubrication is necessary, particularly when taking heavy cuts as, for example, with the roughing tool. Soluble oil is a suitable lubricant for most metals. Cast-iron and brass need no lubricant as their nature causes the turnings to break up and crumble away from the tool.

METAL	LUBRICANT	METAL	LUBRICANT
Tool Steel ...	Soluble Oil Lard	Aluminium ...	Soluble Oil
Mild Steel ...	Soluble Oil	Copper	Soluble Oil
Alloy Steels ...	Soluble Oil Lard	Brass	Soluble Oil or Dry
Cast Iron ...	Dry	Bronze	Soluble Oil
Malleable Castings ...	Soluble Oil		

The point of the " dead " centre should also be occasionally oiled to prevent it becoming heated or unduly wearing the centre-hole of the work revolving on it.

Questions:

1. Name the chief parts of the lathe.
2. Name three cutting tools and state the use of each.
3. Name and describe two functions of the lathe.
4. How would you polish a piece of work in the lathe ?
5. Why are lubricants necessary when turning ?



— SHAPING MACHINE —

THE SHAPING MACHINE.

Classification : The Shaping Machine—familiarly called the "Shaper"—may be classified as a reciprocating machine.

Parts : The main parts of the Shaper are the Pillar or Column, the Ram, the Swivel-head—including the Apron, the Box or Machine Table, the Saddle, the Cross-rail and the actuating mechanism.

Types : There are two main types of Shapers based on the methods of feed, viz. :—

1. The Movable Work type.
2. The Movable Head type.

Use : The chief use of the Shaping Machine is to machine plane, i.e., flat and irregular surfaces that can be most readily obtained by a straight-line cut.

The Planing machine does work of a similar nature to that of a Shaper, differing mainly in the fact that with the former the work moves to the tool whereas with the latter the tool moves to the work. These machines bear to the machining of flat surfaces practically the same relationship that the lathe does to the machining of round work and consequently may be said to rank second only in importance to the lathe in the list of modern workshop equipment.

Methods of Drive (Actuation) : The standard design of shaper is of the pillar or column pattern. The ram operates in a dovetail slide situated on the top of this pillar and in all shapers *the reciprocating action of the ram* is achieved by either one of the following two methods :—

1. **The Crank Drive** : Is one in which a crank is operated by a suitable system of gears working through a rocker arm thus transmitting motion to the ram ; the simple crank drive has been superseded by a crank drive involving a quick return motion, this is intended to speed up the process by reducing the time taken by the ram on its return stroke ; it also has the effect of averaging up the velocity of the ram on the forward stroke.

2. **The Gear Drive**: This provides for a simple rack and gear drive with the necessary reductions—the quick return of the ram being achieved by using either a smaller backing pulley or a higher belt velocity for the return stroke.

The external drive of shaping machines is by means of one of the following three methods :—

(a) Single pulley with constant speed.

(b) Step-cone pulley (with or without back gearing).

(c) Individual electric motor—this method being the one most generally used in up-to-date workshops.

On the front of the pillar is a slide which carries the cross-rail which is adjusted vertically by an elevating screw ; the cross-rail, in turn, carries a saddle to which is secured the box or machine table. This table usually has one horizontal and two vertical faces the latter being square with the former. Each face has several T-shaped slots let into it for clamping purposes. In heavier types of machines the table is supported at the front end by a table brace.

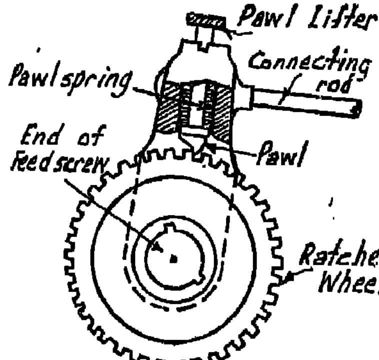
Methods of Feed :

1. **Movable Work type**: With most standard shapers the tool has a forward and backward motion only, the work being traversed either to right or left by the movement of the machine table sliding on a cross-rail.

2. **Movable Head type**: This type of shaper is adapted to the machining of long pieces of work. The machine table is carried on the front face and the arm, corresponding to the ram, moves along the bed, the tool head being fed automatically in or out on the arm, the work remaining stationary on the table.

Traversing Mechanism.

The feed screw of the shaper which transmits movement to the machine table may be turned either by hand or worked automatically. When worked automatically the feed is obtained by causing the feed screw to revolve a portion only of one revolution at a time. This is con-



TRAVERSING MECHANISM

trolled by the action of a pawl and ratchet wheel attached to the end of the feed screw. There are various methods of transmitting the oscillating motion to the pawl, the most common being that of using a train of gears and joining the pawl carrier to a crank pin on the final gear by a connecting rod.

Methods of Cutting :

Most shapers do their cutting on the outward or push stroke, with others known as "Draw Stroke" shapers the reverse is the case, the cut being made on the return or draw stroke, the latter are very useful on heavy work necessitating long strokes.

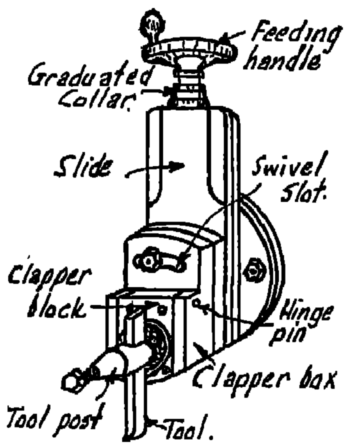
Shaping machines of the standard pattern are made in sizes ranging from a 16-inch stroke up to a 48-inch stroke and are designated as such.

The Tool Head or Carrier :

The type of tool carrier generally used on shapers is the Swivel Head type. This head can be set at any angle from 0° to 90°. There is also a graduated collar on the downfeed screw allowing adjustments to the feed to within one-thousandth of an inch.

The Apron : An important part of the swivel head is the apron, which has a curved slot at the top through which passes a bolt clamping it to the body of the head.

The slackening of this bolt allows a small movement of the apron to right or to left for the purpose of allowing the tool to swing clear on the return stroke in vertical or angular shaping.



SWIVEL HEAD

The Apron comprises the Tool Post, the Clapper Box and Block, and the Hinge Pin.

The tool is held firmly in the tool post; this is attached to the clapper block which, in turn, fits snugly into the clapper box and is held therein by the hinge pin. While the cutting action is in progress the clapper block is forced firmly into the clapper box but on the draw or return stroke the block swings outwards freely on the hinge pin with the result that the tool passes lightly over the work before falling back into its vertical position in readiness for the next cutting stroke.

Formulae for Obtaining the Cutting Speed, Length of Stroke and Number of Strokes Required.

Problem (1): *To find the cutting speed required* when the number of cutting strokes and the length of stroke are known.

Formula :—(No. of strokes per min. $\times$ Length of stroke in inches) $\times$ 0.14 = Cutting speed in ft. per min.

Example :—If the number of strokes per minute is 20 and the length of stroke 6 inches. Calculate the cutting speed in ft. per min.

Cutting speed therefore = $(20 \times 6) \times 0.14 = 16.8$ ft. per minute.

Problem (2) : *To find the number of strokes necessary* when the cutting speed and the length of stroke are known.

Formula :—$\dfrac{\text{Cutting speed in ft. per min.} \times 7}{\text{Length of stroke in inches}} = \text{No. of Strokes.}$

Example :—If the cutting speed is 40 ft. per minute and the length of stroke 8 inches. Calculate the number of strokes per minute required.

No. of strokes therefore $= \dfrac{40 \times 7}{8} = 35$ strokes per min.

Problem (3) : *To find the length of stroke required,* when the cutting speed and the number of strokes per minute are known.

Formula :—$\dfrac{\text{Cutting speed in ft. per min.} \times 7}{\text{Number of strokes per min.}} = \text{Length of Stroke.}$

Example :—If the cutting speed is 50 ft. per min. and the number of strokes 35 per min. Calculate the length of stroke required in inches.

Length of stroke therefore $= \dfrac{50 \times 7}{35} = 10$ inches.

METAL	CUTTING SPEED Feet per minute		AVERAGE FEED RATES Roughing		LUBRICANT	
	Carbon Steel Tools	High-speed Steel Tools	Carbon Steel Tools	High-speed Steel Tools	Roughing	Finishing
Cast Iron { Soft ...	35	60	.078	.093	Dry	Dry
Cast Iron { Hard ...	25	40	.062	.078	Dry	Soda Water
Mild Steel	35	75	.046	.062	Soluble Oil Soda Water	Soluble Oil Soda Water
Cast Steel	25	45	.062	.046	Soluble Oil Lard Oil	Lard Oil
Monel Metal	25	50	.031	.046	Dry Lard Oil	Dry Lard Oil
Brass	40	130	.062	.062	Dry	Dry
Bronze	45	85	.062	.078	Dry Soluble Oil	Dry Soluble Oil
Copper	40	85	.046	.062	Dry Soluble Oil	Dry Soluble Oil
Aluminium	60	120	.078	.093	Dry	Kerosene Soluble Oil
White Metal	60	130	.078	.093	Kerosene Lard Oil	Kerosene Lard Oil

Shaper Tools :

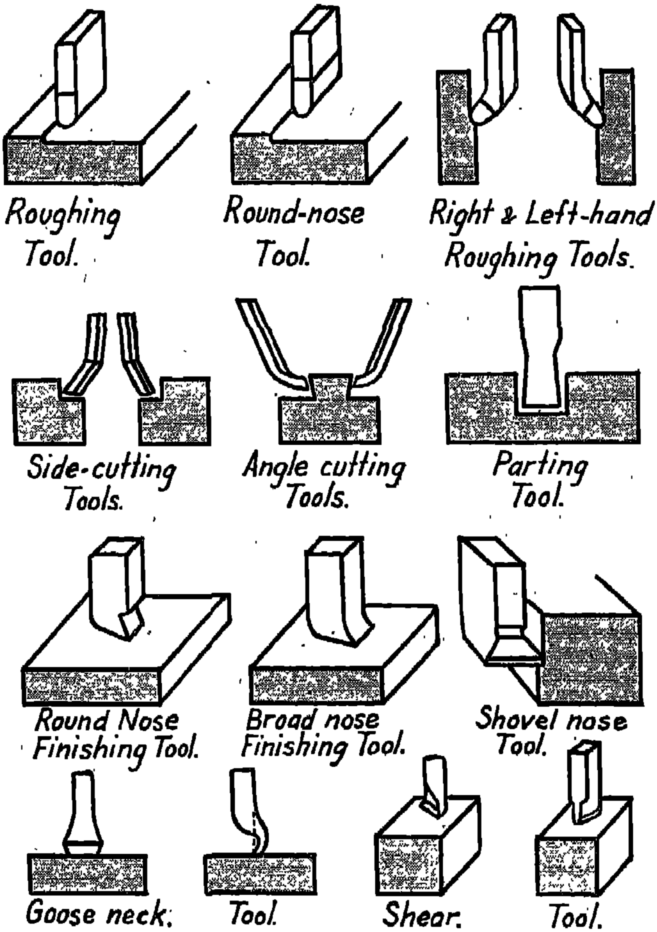
Many of the cutting tools used on the shaper are similar to those used on the lathe, *e.g.*, the roughing, the side cutting, and the parting tools. Solid tools are still used particularly on work of a heavy nature as their strength enables them to withstand heavy stresses, but even with solid tools the tendency is to tip them with such alloys as cemented carbides or "Stellite." Where possible, however, the tool holder and high-speed steel bits are superseding the solid tool for it is much easier, quicker and more economical to grind the bit to the desired shape than to forge a solid tool for the same purpose. Tool holders may be obtained either straight or set to right or left. There is a type that allows the bit to be adjusted to any angle and also a gang tool into which several bits may be fitted. As there is no rocker movement in the tool post shaper tools should, almost without exception, be ground with very little bottom clearance—4° to 8°—with the rake suited to the hardness of the metal being machined. It is advisable whenever possible to have the cutting edge well back under the head so that the spring of the tool and swivel head will not cause the cutting edge to dip into the surface of the work; it also tends to prevent chattering. For under cuts the tool should have a long shank which extends well above the clamp in order that it may be blocked out at the top to overcome any tendency it may have to pivot in the tool post.

The main shaper tools may be grouped under the following headings :—

1. Roughing tools.
2. Side or Facing tools.
3. Finishing tools.
4. Parting or Cutting-off tools.

1. *Roughing tools* are the tools used to bring the metal down to near the finished size. They are made right- or left-handed with no top rake; they have a side rake of from 6° to 20°, depending on the hardness of the metal being cut.

2. *Side or Facing tools* are made either right- or left-handed and are also made both as roughing and finishing



TYPES OF SHAPING TOOLS.

tools depending upon the work they are called upon to do. They are used for making vertical and angular cuts.

Shovel-Nose tool has its cutting edge as the widest part. It is very useful for cutting down vertical faces, and has the corners slightly rounded. It can be made either right- or left-handed.

3. *Finishing tools* are the tools used to finish the work to the required dimensions; they have a broad cutting edge. These tools are sometimes made with a convex cutting edge instead of a flat edge as the former tends to produce a better finish. The cut taken by this tool should be less than its width in order to allow a little overlap.

Spring tool or Gooseneck is used when a high finish is required. It is the tool generally used for finishing cast-iron. As a result of its construction there is very little tendency for it to chatter or dig into the work.

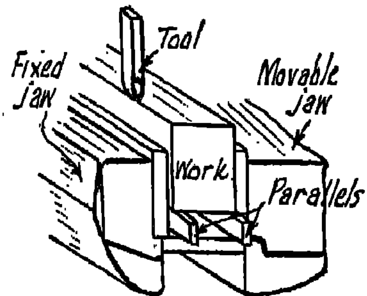
Shear tool is used to obtain a very high finish on steel. The blade is approximately $\frac{3}{16}$-inch thick and is twisted about 15° before being ground slightly convex on the cutting edge.

4. *Parting or Cutting-off tools* are used for cutting grooves or slots, squaring corners and for cutting off work. If the groove is wide enough it is cut with a roughing tool and the parting tool used for finishing off.

Shaper Accessories:

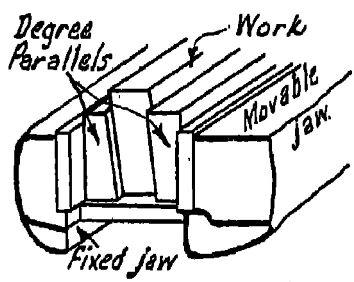
1. *The Shaper Vice*: A considerable amount of shaper work can be held in the vice which is considered a regular shaper attachment and is always furnished with the machine. As with other vices, the shaper vice has a fixed and a movable jaw, having the advantage also of a swivel action at the base allowing the jaws, and consequently the work, to be turned to any angle, the base being graduated in degrees. As a result of this device it is possible to do angular shaping in the horizontal plane.

2. *Parallel Strips* are strips of mild steel of various sizes usually case-hardened in order to protect the edges. They are generally made in pairs and are very useful for raising the level of work to be machined, for example, to bring the job above the level of the vice jaws.



USE OF PARALLELS

3. *Degree Parallels* are also made in pairs. They are similar to parallel strips with the exception that one side of each parallel is planed at an angle in order that work may be held in a slanting position.

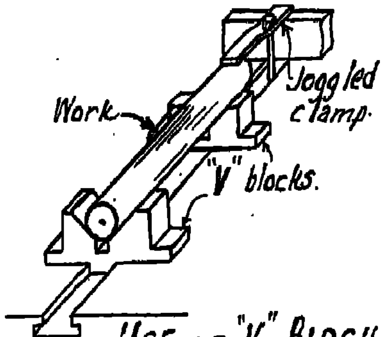


USE OF DEGREE PARALLELS

4. *Levelling Wedges* are very useful where the points of support vary in height. When carefully made they form a good support and can be used to make fine adjustments for height either directly on the machine table or on the top of other supports.

. LEVELLING WEDGES.

5. *V-blocks* are used for holding round work. It is an advantage to have the blocks tongued to fit into the table grooves thus eliminating any tendency to move.



USE OF "V" BLOCKS.

6. *Angle or Knee Plate* is usually made of cast-iron and is machined in the form of a right angle. When in use one side is bolted to the table the other being used for the purpose of bolting work to it or as a rest against which work may be clamped.

7. *Fixtures*: Shaper fixtures are designed to hold the work in a definite position on the machine table. They are generally fitted with their own clamping devices and are particularly useful for repetition work, that is, where many similar pieces of work have to be produced as they facilitate the process of "setting up" the work.

8. *Jigs* are somewhat similar to fixtures in that they hold the work in a fixed position and, as with a fixture, each has to be designed to meet the particular requirements

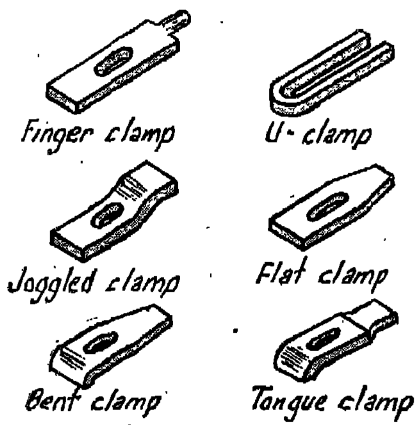
of a certain job. A jig also has the additional advantage to the machinist of helping to guide the cutting tool during the operation.

9. *Clamps*: Various types of clamps are indispensable for securing work on the machine table the most useful being :—

(a) *The Flat Clamp*: This may be either parallel in width or tapered.

(b) *The U-Clamp*: Is made of square steel and is left open at one end for easy removal.

(c) *The Joggled Clamp*: Is set down or joggled so that the nut of the holding-down bolt will not foul the cutting tool.

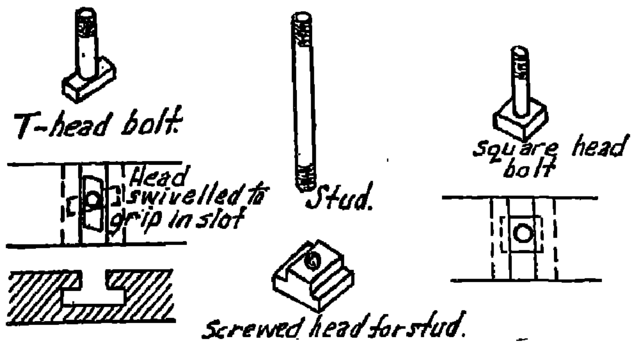


TYPES OF CLAMPS

All of these fittings are drilled to receive the holding-down bolts. It is an added advantage if these holes are elongated.

10. *Clamping Bolts*: These bolts, whose primary function is the holding down of work on the shaper, must have their heads of such a shape that they will fit snugly into the T-shaped slots in the top or sides of the machine table.

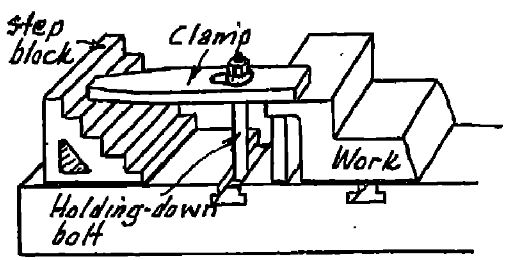
(a) *The Square-Head Bolt*: This is the one most commonly used. It is necessary with this type to slide it in from the end of the slot.



TYPES OF CLAMPING BOLTS

(b) *The T-Head Bolt*: With this type the head is shaped so as to fit into the table slot from the surface. It is oblique at the ends and is pivoted on the shank so that when the bolt is tightened it moves sufficiently to grip within the "T" of the slot.

(c) *The Tapped Head and Stud Bolt* has the head and shank separate. The head is shaped like a "T" to fit into the T-shaped slot of the table and is tapped to receive the shank which is in the form of a stud. Its chief advantage is that shanks of various lengths may be used without the necessity of removing the head from the slot.



USING THE STEP-BLOCK.

11. *The Clamping Block* is a step-shaped, machined cast-iron block used in conjunction with clamps for the purpose of keeping the latter horizontal when pressure is applied by the bolt.

12. *Shims or Packing Pieces* are strips of steel, brass, or copper of various thicknesses used either for packing up to a height or for the protection of finished surfaces from clamps, dogs, etc.

Methods of Holding Work:

The securing of work on the shaper before commencing operations is an important step towards the production of good work and depends largely upon the correct use of the accessories dealt with above. As the variety of work done on the shaping machine is great the operator continually finds himself up against problems requiring good judgment and careful execution, also in most cases more skill is required in the setting up of the work than in the machining.

Three important points to be considered before setting up the work are :—

(1) The shape and construction of the piece or part to be machined.

(2) The machining operations involved and the amount of metal to be removed.

(3) The accessories available.

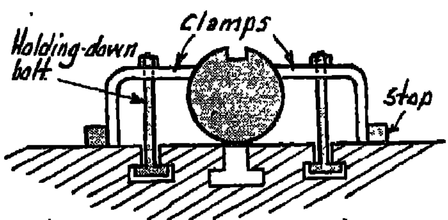
It is necessary to use the equipment available correctly and to the best advantage. Some suggestions for so doing are set out as follows :—

(1) *Using the machine vice*: When holding work in the vice the longer side should be in contact with the jaws, also the work should be so placed that its length is covered by the stroke in order to reduce the number of cuts necessary to remove the surface.

(2) *Holding thin work in the vice*: If a thin piece of metal is to be machined it is necessary to rest it on a parallel strip and to use "grippers" to hold it. Grippers are steel

strips of triangular section which are placed one on each side of the work with the broad edge against the jaw and the narrow edge against the work to allow clearance when machining.

(3) *Holding work on the table*: When work is to be clamped directly to the machine table it is usually done with the aid of suitable clamps and holding-down bolts. One end of each clamp rests on the job with the other end built up by means of a step (clamping) block, or packing pieces to keep the clamp horizontal. The clamps are then tightened down on to the work by means of the holding-down bolts, whose heads are fitted into the T-shaped slots of the table. Again, when using the vice, the work should be "set up" so that its greatest length is covered by the stroke of the tool.



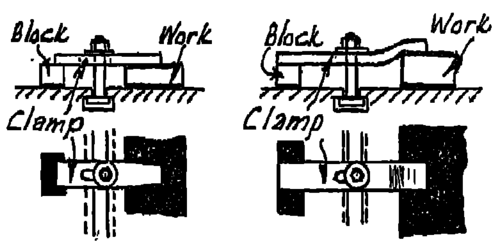
A METHOD OF HOLDING CIRCULAR WORK

(4) *Using the Angle Plate*: The Angle plate is generally used when machining an edge at right angles to an existing face. The work to be machined is set straight and true with the aid of a surface gauge and then clamped securely in position with "G" clamps. The Angle plate is also used as a rest and as a "stop" to take the thrust of the cut.

(5) *Using the "V-Blocks"*: Sometimes cylindrical work is clamped directly to the table but more often it is seated in the "V" of the V-blocks which are generally used in pairs. The work is then clamped to the machine table in the normal way with the aid of clamps and holding-down bolts.

(6) *Using a Fixture*: The use of a fixture depends largely upon the particular type required. Whenever possible they are made with their own clamping device. Sometimes they are designed to fit into the T-slots of the table, the projecting part acting as a rest against which the work is clamped.

(7) *Using the Clamps*: The method of clamping and the particular type of clamp used depends upon the machining operation to be performed. There are several points in their use, however, that may well be stressed :—



CORRECT USE OF CLAMPS

(a) Be sure the clamp is clear of the travel of the tool.

(b) The clamp should be horizontal and have a firm seat both on the work and on the packing.

(c) Always locate the points of clamp pressure directly over the points of support.

(d) The clamping bolt should be as near to the work as conditions permit, with the blocking for the outer end as far away from the bolt as convenient, thus throwing the greatest weight on to the work.

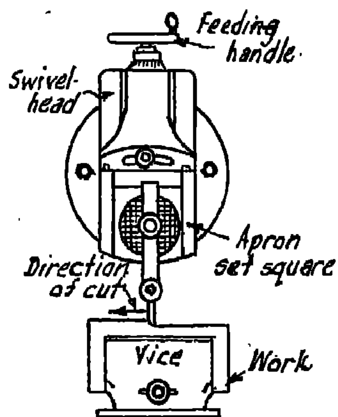
(e) Always protect the work, particularly finished surfaces from the action of the clamps, by placing copper or brass strips between them.

Shaper Operations and Exercises :

As there are usually more ways than one of doing every piece of work, the operator should carefully study the way in which it can best be done. The manner in which the work is set up, the kind of tools to be used and the efficient handling of the machine itself all have an important bearing on the quality and quantity of the work produced.

Exercise 1.—*Shaping a Horizontal surface* :

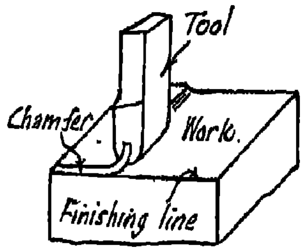
The work should be "set up" on the machine table so that it can be tested for size and squareness when necessary and as many surfaces as possible machined at the one setting. Where the work is of a small nature, it may be held in a vice, but if large it will be clamped directly to the machine table by a suitable holding-down device and with its greatest length covered by the stroke of the tool.



SURFACE SHAPING

The work should be placed so that the tool has about an inch of travel before commencing its cut on the metal; the tool should not continue far beyond the end of the cut as an excessive amount of overtravel means a loss of time. There is also a tendency for the movement of the tool to

cause the edge of the metal to chip. This latter may be overcome, however, by filing a chamfer on the edge of the work down to the finishing line.

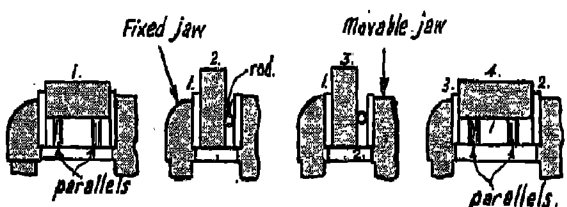


The roughing cuts should be as heavy and at as coarse a feed as the machine can conveniently handle and the strength and character of the work will permit

Exercise 2.—Shaping a Rectangular block :

To shape a rectangular block square and parallel the following procedure is adopted :—

(a) Machine one of the larger faces, gripping the work securely in the vice and using a pair of parallel strips to raise the surface above the level of the vice jaws.



PROCEDURE IN SHAPING RECTANGULAR BLOCK

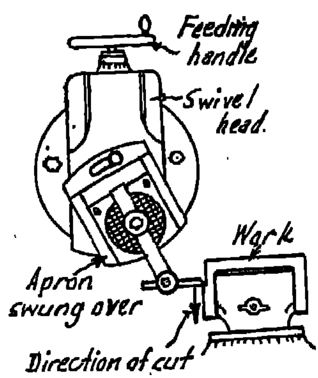
(b) Machine one of the adjacent sides square to the first side. It is advisable to have the side already machined resting against the fixed jaw of the vice and to have a small straight rod placed lengthwise between the movable jaw and the fourth side of the

work. This ensures an even pressure throughout its length and overcomes any tendency towards irregularity on the part of the movable jaw.

(c) Machine the third face, i.e., the face opposite the second by placing the second face towards the base of the vice, still keeping the first face against the fixed jaw and again using the rod to maintain even pressure as in Step (b).

(d) Machine the fourth face as in Step (a), having the first face downwards and resting on the parallel strips with faces 2 and 3 gripped by the jaws of the vice, face 3 being towards the fixed jaw.

The work must be tested for truth at each step, using the Square to test the angles and the Calipers to check dimensions and test for parallelism.



VERTICAL SHAPING

Exercise 3.—*Shaping a Vertical surface*:

It is essential in vertical shaping to so hold the work that the tool can complete its vertical cut at one setting. It is necessary, therefore, before commencing the cut, to have the tool slide well up towards the top of the Head. Once again, small work may be held in the vice,

larger work being transferred to the table. Care must be taken in the latter case, to ensure that the holding-down devices, *e.g.*, clamps, etc., in no way foul or interfere with the free action of the tool.

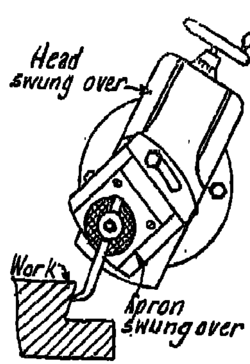
The width of the cut is arranged by adjusting the position of the table on the cross-rail, the feed (downwards) being supplied by movement of the tool slide in the tool head, with the latter set square. To allow clearance for the tool on the draw stroke the apron is set at a suitable angle away from the direction of the cut, the movement of the clapper block working on the hinge pin then allows the tool to swing clear of the work.

Exercise 4.—Combining Horizontal and Vertical shaping:

This is a combination of Exercises 1 and 3, and involves the shaping of a piece of work having faces at right angles to each other without altering the setting. Firstly, the horizontal cut is completed, the movement of the machine table supplying the traverse motion with the tool head and apron set square. Secondly, the vertical cut is made, the table being stationary and the feed supplied by movement of the tool slide, the head remaining square as before, with the apron swung over as in Exercise 3 to allow tool clearance on the draw stroke.

Exercise 5.—Shaping an Angular surface:

Angular cutting can be an intricate and tedious process



ANGULAR SHAPING.

involving many pieces of equipment, *e.g.*, the Universal table. Simple internal and external angles may, however, be cut by adjustment of the tool head and/or apron to suitable angles, the feed being by movement of the tool slide.

Exercise 6.—Shaping a " V " Block:

The first step in the shaping of a V-block is to machine the rectangular block required as set out in Exercise 2 after which the shape and size of the " V " slot is marked out on each end. The tool head is then set to the necessary angle and the metal removed from the slot with the straight (round-nose) roughing tool. The feed is supplied by the tool slide and the traverse motion by movement of the cross slide. The next step is to machine each side of the " V " separately, using the side finishing tools and finally to cut the clearance groove at the bottom with a parting tool.

Exercise 7.—Parting or Cutting off work:

The cutting off of work or pieces of bar stock is done vertically using a parting tool, with plenty of back clearance to prevent binding in the groove. The metal is held in the vice with the part to be cut off projecting beyond the jaws. There is no movement of the machine table the feed being controlled by the tool slide.

Questions :

1. What are the chief functions of the Shaping machine ?
2. Why is the " Shaper " classified as a reciprocating machine ?
3. What is the advantage of the " quick return " action of the drive ?
4. Name and state the use of *four* shaper tools.
5. Name, describe and state the use of *four* shaper accessories.

BELTS, PULLEYS AND POWER TRANSMISSION.

The transmission of power by belts is a subject of great importance and one that should receive thought and study on the part of the engineer.

Definition: *A belt is a flexible band passing over two or more pulleys for the purpose of transmitting motion from one to the other.* As its drive depends on its frictional resistance to slipping and as it is of a more or less elastic nature, it cannot be depended upon to transmit exact velocity ratios.

Classification: Belts may be divided into three main classes, viz. :—

(1) *Flat belts*: For use on flat or crowned pulleys.
(2) *Round belts*: For use on grooved or sheave pulleys.
(3) "*V*" *belts*: For use on V-shaped grooved pulleys.

Materials: The materials used are leather and cotton-plyed rubber for flat belts, leather, cotton, manila and cotton-plyed rubber for round belts, and cotton-plyed rubber for "V" belts.

Leather belts have stood the test of time; their elasticity is an important factor and depends largely on the original quality of the leather and the treatment it receives.

Best quality leather belting is made from the prime or butt part of the hide, which has little or no stretch. Such a belt properly tanned and treated will give excellent service for years.

When belts are required heavier than the thickest hides will make, two or more thicknesses are joined together giving double and triple ply belting. For drive belts it is better to use a double ply belt than a single belt of greater width.

Care of Belts: A good idea with a piece of new leather belting is to hang it up for several days with weights attached to one end. This will eliminate any stretching of the belt when put into use and so perhaps save trouble.

During use, belts should be inspected frequently in order to see whether or not they need attention, and whether a dressing is necessary. The object of dressing a belt is not only for preservation but also to increase its coefficient of friction, thus enabling it to pull a heavier load with a given tension.

Belt Dressings : Leather belts should be cleaned and greased every five or six months to give the grain side a soft adherent surface. The following mixtures are recommended :—Take two parts of beef tallow to one part of cod liver oil (by weight) ; melt the tallow and allow it to cool until the finger can be inserted then add the cod liver oil and stir until cold. A light coat of this mixture should be applied to the driving side of the belt after cleaning.

Rubber belts can be dressed with a mixture consisting of equal parts of red lead, black lead, french yellow and litharge, mixed with boiled linseed oil and enough japan to make it dry quickly.

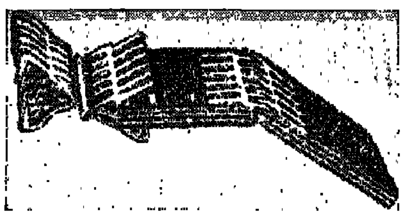
Resinous compositions should never be used to prevent belts slipping, for although they may give temporary adhesion the belt soon becomes glazed and slips more than before. Mineral oils injure leather belting by penetrating and driving out the original lubricants. Where a belt has become saturated with lubricating oil it should be scraped with a wooden scraper and then packed in some absorbent substance, *e.g.*, sawdust, for a few days before being again put into service.

Animal oils or grease should never be used on rubber belting.

Leather belts that are occasionally washed in warm water and afterwards greased and dried will give many more years of service than those which are neglected. It should be remembered, however, that although belts should never be allowed to become dry or stiff the too liberal use

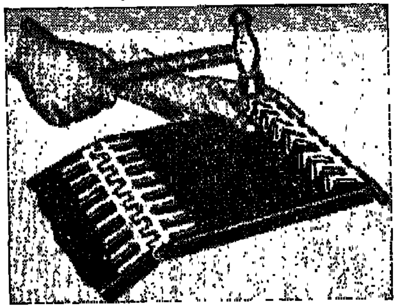
of dressings will also tend to shorten their lives. An endeavour should therefore be made to achieve the happy medium in this respect.

Fastening devices : The joining of belts is a matter of much importance and sufficient care is not generally exercised in this direction. When a belt is loose it slips on the pulleys with a consequent loss of efficiency. On the other hand, over tight belts cause over-heating, increase the friction on the bearings and draw shaftings out of alignment apart from the damage caused to the belt itself by over-stretching.



TYPE OF FLEXIBLE METAL LACING.

There are numerous fastening devices, the time-honoured method of lacing with raw-hide thongs having been almost completely superseded by metal fasteners of one type or another, such as bronze wire lacings, belt hooks, clips and studs. And where there is trouble in this respect it arises usually not from the fastener itself but from its incorrect application. When making a joint and using any kind of fastener the belt must be cut square, a try-square being used to ensure this. It is also very necessary to hold the ends squarely together while the fastening is being made. The holes should be punched exactly opposite each other and be as small as possible for the particular type of lacing used. Also the lacing on the pulley side of the belt should run parallel to the length of the belt and not across itself as this makes a rough surface and causes the lacing to wear out very quickly.



JOINING A BELT.

Methods of Using Belts: Generally, belts are used to connect parallel shafts, the most common being :—

(1) *Open belts* : When the shafts are required to rotate in the same direction.

(2) *Crossed belts* : When the shafts are required to rotate in opposite directions.

The "Arc of Contact" in regard to belting is that portion of the pulley's surface in contact with the belt. It is obvious, therefore, that a crossed belt will transmit more power than an open belt by reason of the fact that more of it is in contact with the pulley.

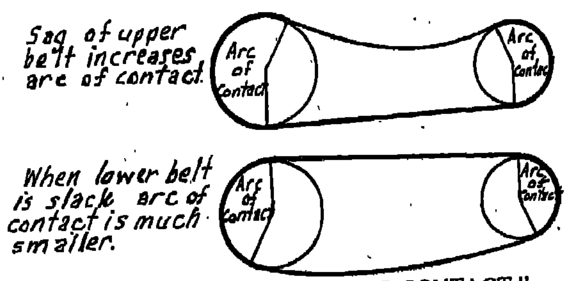


DIAGRAM SHOWING "ARC OF CONTACT."

The adhesion of a belt to a pulley depends largely on the condition of the belt and pulley surfaces as well as the weight and tension of the belt. This latter point is important, for when shafts are reasonably far apart the

weight of the belt itself adds considerably to its adhesion and consequently to its power of transmission, whereas when the shafts are close together extra tension must be given to the belt to make up for this deficiency.

All belts should run with the slack side on top, i.e., the lower side should be the driving or tension side. This method increases the arc of contact by causing more of the belt to be in contact with the pulley at the one time and increases the power drive by as much as 20 per cent. It is advisable to make an exception to this rule if the belt is running in a place where the air is full of abrasive dust, in which case it is better to have the slack at the bottom as the flap or vibration of the belt tends to shake off the dust, which may otherwise be carried around and do damage both to the crown of the pulley and the belt itself.

"V" Belts : Are extensively used in modern engineering practice. They offer many useful advantages, *e.g.*,

1. They permit of a large speed ratio, the wedge action compensating for the low arc of contact on the smaller pulley.
2. Closer centres can be employed.
3. Freedom from vibration and noise
4. Quick and easy replacement.

Pulleys : May be divided into two groups :—

(a) Whole (b) Split.

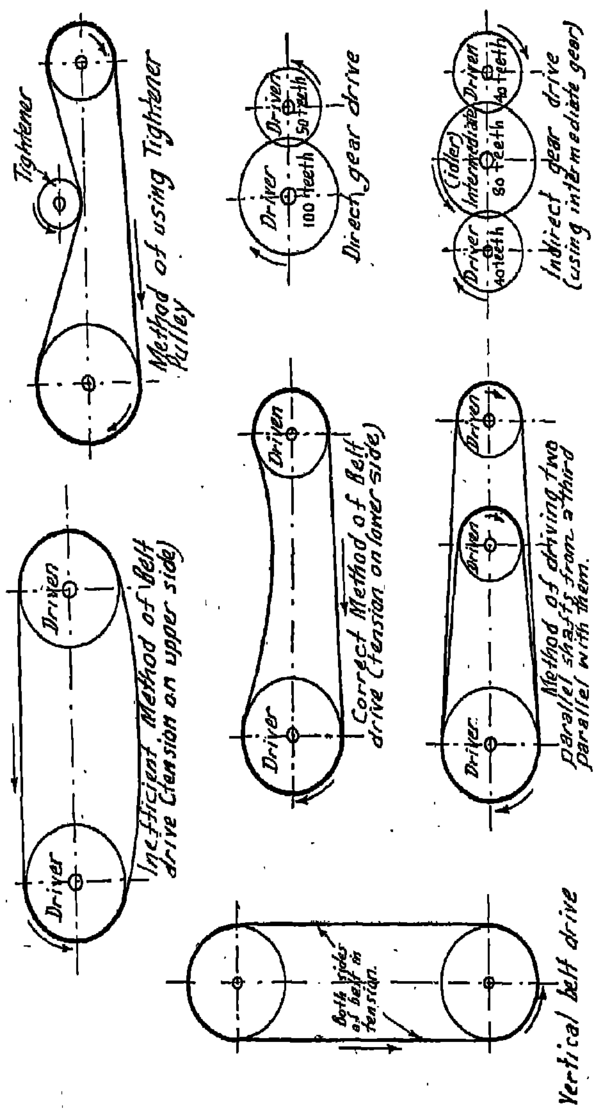
(a) *The Whole Pulley* is made in one piece and fitted on to the shaft from the end.

(b) *The Split Pulley* is made in halves and can be put on to the shaft at any point in its length.

Pulleys are made of :—

(a) Metal. (b) Wood.

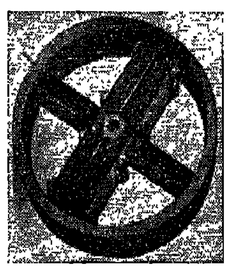
(a) *Metal Pulleys* are made of cast-iron or mild steel. Cast-iron pulleys of large diameter are made in sections and when wide have a double set of arms or spokes. A type in common use is one having a heavy cast-iron hub or spider and a mild steel band riveted to the arms. This type is light and strong and well-suited to all classes of work.



TYPES OF BELT AND GEAR DRIVES.

TYPES OF METAL PULLEYS.

(b) *Wood Pulleys* are made of hard wood. They are built up in small sections by glueing and are turned true on a lathe after which they are fitted with bushes of the required diameter and clamped to the shaft by means of a clamp hub. On account of their lightness, wooden pulleys are well suited to high-speed work.

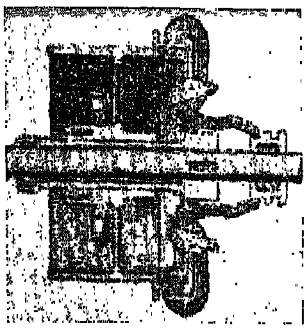


TYPE OF WOOD SPLIT PULLEY.

Pulleys are also referred to as "fast" or "loose," depending on whether they are secured to a shaft by means of some fastening device or are free to move on it.

Pulleys are also "straight" or "crowned," depending on the shape of the face. The straight pulley is flat across the face and is used for shifting belts, i.e., belts that are required to slide from one pulley to another. The crowned pulley has a slightly curved or convex face. It is used for non-shifting belts.

Clutch: It is sometimes necessary to stop or start a pulley without interfering with the movement of the shaft. To do this, the pulley is slid towards a clutch, which is fitted on to the shaft and, by the action of a sleeve on the pulley, the jaws of the clutch are released and firmly grip the face of the pulley.



CLUTCH PULLEY.

Shafting: Pulley shafts used for the transmission of power are made of mild steel finished smooth, round and true, either by the processes of turning or cold rolling.

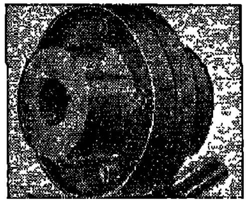
(a) *Turned Shafting*: When shafting is turned in the lathe its final true surface is achieved by passing a hollow reamer along its length.

(b) *Cold Rolled Shafting* is given its final finish by a cold rolling process which not only gives it a smooth true finish but also stiffens and intensifies the fibres of the metal.

Couplings: When a number of lengths of shafting are to be joined together a suitable coupling is necessary.

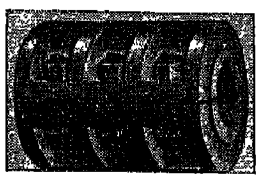
The most common types employed are :—

(a) *Flanged coupling*: It is an advantage to fit this type to the end of the shaft and then machine the faces, thus ensuring a true and sure connection.



FLANGED COUPLING.

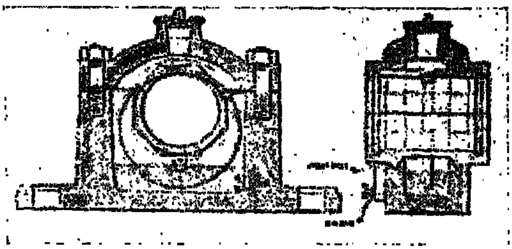
(b) *Compression couplings* are made in many designs. They consist of two semi-circular shells bolted together. The ends of the connected shafts meet in the centre and are carefully fitted. As with the flanged coupling a key driven into a key-way at each end makes the drive positive.



COMPRESSION COUPLING.

Bearings : Shafting must be supported or carried by means of suitable bearings. These may either rest on a beam or girder or be mounted in what are known as brackets or hangers. A hanger is a cast-iron frame suspended from an overhead support or it may be in the form of a bracket attached to a post or column.

The bearings may be of a simple plummer block type lined with brass and lubricated by means of oil grooves or the more expensive and efficient self-oiling type lined with a good grade bearing metal and fitted with a ring oiling device in which a ring running on the shaft carries up oil from a reservoir at the base of the bearing.



TYPE OF OIL RING BEARING.

Power Transmission : The transmission of power from one line of shafting to another or to a machine is accomplished by using belts or gears. The drive may be either direct or indirect and may be a complete belt drive, a complete gear drive or a combination of both.

(a) *Belt Drive* : When the pulleys are connected by belt, motion and consequently power, is transmitted by friction from the driving pulley to the driven pulley. The power that can be transmitted by belt, varies greatly, depending on conditions. It is therefore unwise to make use of fixed rules for the calculation of belt powers without bearing this fact in mind.

If both the driver and the driven pulleys are the same diameter the revolutions of each will be the same, but if the diameter of the driving pulley is twice that of the driven pulley it will only revolve half as fast by reason of the fact that the driven pulley will then complete two revolutions to every one of the driver pulley.

A pull of 33,000 lbs. through a space of one foot in one minute represents one horsepower of work, therefore a pull of 33 lbs. through a space of 1,000 ft. in one minute would represent the same amount of work and by increasing the velocity or the tension of the belt the work performed is correspondingly increased. The working strain that can be placed on a sound leather belt ranges from 40 to 60 lbs. per inch of width for a single belt and double this for a double belt where the thickness is twice that of the single belt.

The following formulae may be used for calculating horse-power :—

(1) For finding h.p. transmitted (single leather belting):—

Formula :

$$\text{H.P.} = \frac{W \times V}{800}$$

Where W = Width of belt in ins.
,, V = Velocity of belt in ft. per min.
,, H.P. = Horse-power.

Example : A 6-inch single belt is travelling at 2,000 ft. per min. Calculate the H.P. transmitted.

$$\text{H.P.} = \frac{6 \times 2000}{800} = 15 \text{ H.P.}$$

(2) For finding H.P. transmitted (double leather belting) :—

Formula :

$$\text{H.P.} = \frac{W \times V}{550}$$

Example : A 9-inch double belt is travelling at 3,000 ft. per min. Calculate the H.P. transmitted.

$$\text{H.P.} = \frac{9 \times 3000}{550} = 49 \text{ H.P.}$$

Note : A common rule is to allow one inch of width at 1000 ft. per min. for every horse-power required when using single belting, and one-half inch of width when using double belting.

Formulae for Calculating Diameters and Speeds of Pulleys and Shafts.

Problem (1) : *To find the speed of a driven or countershaft pulley* when the diameter and speed in revolutions per minute of the driving pulley and the diameter of the driven pulley are known.

Formula :

$$\frac{\text{Diameter of Driving Pulley} \times \text{Speed of Driving Pulley}}{\text{Diameter of Driven Pulley}} = \text{Speed of Driven Pulley in r.p.m.}$$

Example : If the diameter of the driving pulley is 12 inches, its speed 150 r.p.m. and the diameter of the driven pulley 8 inches. Calculate the speed of the driven pulley.

$$\text{Speed of driven pulley therefore} = \frac{12 \times 150}{9} = \begin{array}{c}200\\ \text{r.p.m.}\end{array}$$

Problem (2) : *To find the speed of a driving pulley* when the diameter of the driving pulley, the driven pulley and the speed in r.p.m. of the driven pulley are known.

Formula :

$$\frac{\begin{array}{c}\text{Diameter of}\\ \text{Driven Pulley}\end{array} \times \begin{array}{c}\text{Speed of}\\ \text{Driven Pulley}\end{array}}{\text{Diameter of Driving Pulley}} = \begin{array}{c}\text{Speed of}\\ \text{Driving Pulley}\\ \text{in r.p.m.}\end{array}$$

Example : If the diameter of the driven pulley is 9 inches, its speed 600 r.p.m. and the diameter of the driving pulley 18 inches. Calculate the speed of the driving pulley.

$$\text{Speed of driving pulley therefore} = \frac{9 \times 600}{18} = \begin{array}{c}300\\ \text{r.p.m.}\end{array}$$

Problem (3) : *To find the diameter of a driven pulley* when the diameter and speed of the driving pulley and the required revolutions per min. of the driven pulley are known.

Formula :

$$\frac{\begin{array}{c}\text{Diameter of}\\ \text{Driving Pulley}\end{array} \times \begin{array}{c}\text{Speed of}\\ \text{Driving Pulley}\\ \text{in r.p.m.}\end{array}}{\text{Speed of Driven Pulley in r.p.m.}} = \begin{array}{c}\text{Diameter of}\\ \text{Driven Pulley.}\end{array}$$

Example : If the diameter of the driving pulley is 15 inches, its speed 120 r.p.m. and the required speed of the driven pulley 300 r.p.m. Calculate the diameter of the driven pulley.

$$\text{Diameter of driven pulley therefore} = \frac{15 \times 120}{300} = \begin{array}{c}6\\ \text{ins.}\end{array}$$

Problem (4) **:** *To find the diameter of the driving pulley* when the diameter and speed of the driven pulley and the speed of the driving pulley are known.

Formula :

$$\frac{\text{Diameter of Driven Pulley} \times \text{Speed of Driven Pulley in r.p.m.}}{\text{Speed of Driving Pulley in r.p.m.}} = \text{Diameter of Driving Pulley.}$$

Example : If the diameter of the driven pulley is 30 inches, its required speed 200 r.p.m. and the speed of the driving pulley 600 r.p.m. Calculate the diameter of the driving pulley.

Diam. of driving pulley therefore $= \dfrac{30 \times 200}{600} = 10$ ins.

Note : Approximately 25% of the power energy transmitted is absorbed by the main and counter shafts, thus leaving only 75% to be converted into useful work beyond this point.

(*b*) *Gear Drive* : The term gearing is often used in a general sense to denote all means of transmitting motion, but more especially does it apply to the method whereby motion is transmitted from one shaft to another by means of toothed or gear wheels. There is a type of drive known as a "friction drive," wherein two smooth faced wheels are brought into contact, one driving the other by means of the friction created. This type of drive is not extensively used, its great weakness being that when the power transmitted exceeds the frictional resistance, slipping occurs, making it impossible to fix a definite relationship between the two wheels. To overcome this weakness and to design a type of gearing in which the velocity ratio would be absolutely determined, it was found necessary to form teeth on the outer surface (periphery) of the wheels, teeth that would mesh smoothly with those of other wheels and so create between them a positive drive.

The same facts apply to the relative speeds of gear wheels as to pulleys, therefore, if a driving gear with

100 teeth is meshed with a driven gear having 50 teeth the latter will rotate twice as fast as the former, i.e., it will *complete two revolutions to one of the driving gear.*

Data and Formulae for Calculating Speeds of Gearing.

Diameter: when applied to gears is always understood to mean the Pitch Diameter.

Pitch Circle: All gears have an imaginary circle called the "pitch circle," which corresponds to the circumference of the wheels and are the circles which would be in contact were the tops of the teeth cut off.

Pitch Diameter: is the distance across the pitch circle, measured through the centre. It is commonly referred to as the pitch circle diameter (p.c.d.).

Diametral Pitch: is the number of teeth to each inch of the pitch diameter. Nearly all gear calculations are made in terms of the diametral pitch.

Addendum: is that part of the tooth outside the pitch circle.

Dedendum—or "Land"—is that part of the tooth inside the pitch circle.

Face: is that part of the teeth outline outside the pitch circle.

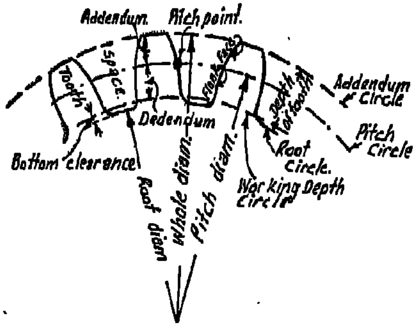
Flank: is that part of the tooth outline inside the pitch circle.

Pitch Point: is where the face and flank join at the pitch circle.

Addendum Circle: passes through the tops of the teeth and is the whole, outside or blank diameter of the gear.

Root Circle: passes through the bottoms of the teeth.

Circular Pitch: is the distance measured on the pitch circle from the pitch point of one tooth to the corresponding point on the next tooth.



DATA FOR GEAR WHEELS.

The formulae given above for belt and pulley drives can also be used to determine the relative speeds of shafts connected by spur and bevel gears, provided the "pitch diameter" or the number of teeth in the gear is substituted for the pulley diameter in each case, *e.g.* :—

Problem (1) : *To find the speed of the driven gear* when the number of teeth in the driving gear, its speed and the number of teeth in the driven gear are known.

Formula :

$$\frac{\text{No. of teeth in Driving Gear} \times \text{Speed of Driving Gear in r.p.m.}}{\text{No. of teeth in Driven Gear}} = \text{Speed of Driven Gear in r.p.m.}$$

Example : If the driving gear has 30 teeth, revolves at 100 r.p.m. and the driven gear has 60 teeth. Calculate the speed of the driven gear.

$$\text{Speed of driven gear therefore} = \frac{30 \times 100}{60} = 50 \text{ r.p.m.}$$

Problem (2) : *To find the pitch diameter of a driven gear*, when the pitch diameter of the driving gear, its speed and the required speed of the driven gear are known.

Formula :

$$\frac{\text{Pitch diam. of Driving Gear} \times \text{Speed of Driving Gear in r.p.m.}}{\text{Speed of the Driven Gear in r.p.m.}} = \text{Pitch diam. of Driven Gear.}$$

Example: If the pitch diameter of the driving gear is 6 inches, its speed 80 r.p.m. and the required speed of the driven gear 40 r.p.m. Calculate the pitch diameter of the driven gear.

Pitch diameter of driven gear therefore $= \dfrac{6 \times 80}{40} = 12$ inches.

Problem (3): *To find the number of teeth required* in a gear when the pitch circle diameter and the diametral pitch are known.

Formula:

Pitch diameter $\times$ Diametral pitch $=$ No. of teeth in gear.

Example: If the diameter of the pitch circle is 12 inches and the diametral pitch is 4 inches. Calculate the number of teeth required.

No. of teeth required therefore $= 12 \times 4 = 48$ teeth.

Problem (4): To find the number of teeth required in a gear when the outside (addendum circle) diameter and the diametral pitch are known.

Formula:

(Outside diam. $\times$ Diametral pitch) — 2 $=$ No. of teeth in gear.

Example: If the outside diameter is 8 inches and the diametral pitch 4 inches. Calculate the number of teeth required.

No. of teeth required therefore $= (8 \times 4) - 2 = 30$ teeth.

Problem (5): *To find the Pitch Diameter* (*p.c.d.*) when the number of teeth and the diametral pitch are known.

Formula: $\dfrac{\text{No. of teeth in gear}}{\text{Diametral Pitch}} =$ Pitch Diameter.

Example: If the number of teeth in gear is 50, and the diametral pitch is 5. Calculate the pitch diameter.

Pitch Diameter therefore $= \dfrac{50}{5} = 10$ inches.

Problem (6) **:** *To find the outside diameter* (or blank size) of a gear when the number of teeth and diametral pitch are known.

Formula : $\dfrac{\text{Number of teeth} + 2}{\text{Diametral Pitch}} = \text{Outside Diameter of Gear.}$

Example : If the number of teeth in gear is 70 and the diametral pitch is 6 inches. Calculate the outside diameter.

$$\text{Outside diameter therefore} = \frac{70 + 2}{6} = \frac{72}{6} = 12 \text{ inches.}$$

Problem (7) **:** *To find the distance between centres* of two gears when the number of teeth and the diametral pitch are known.

Formula :

$$\frac{\frac{1}{2}\,(\text{No. of teeth of both gears})}{\text{Diametral Pitch}} = \text{Distance between centres.}$$

Example : If the number of teeth in the gears is 70 and 50 respectively, and the diametral pitch is 6 inches. Calculate the distance between centres.

Distance between centres therefore =

$$\frac{\frac{1}{2}\,(70 + 50)}{6} = \frac{\frac{1}{2}\,(120)}{6} = \frac{60}{6} = 10 \text{ inches.}$$

Intermediate Gears : These gears function in two ways, viz. :—

(a) For the purpose of connecting the driving and the driven gears when they are too far apart to mesh.

(b) For changing the direction of rotation.

The introduction of intermediate gears in no way increases or decreases the number of revolutions of connected gears, therefore, if one or more intermediate gears are placed in a direct train between the driving and the driven gears the speed ratio remains unaltered.

Questions :

1. Define the use of a belt.
2. How are belts classified ?
3. What purpose is served by "open" belts and "crossed" belts ?
4. What is meant by the "Pitch circle" and the "Diametral pitch" of a gear ?
5. Give *two* reasons for using intermediate gears.

FORGE WORK.

Forging may be defined as the shaping and joining of steel and wrought-iron by hammering, or pressing, under the influence of heat. There are few set rules that can be laid down in forge work for the guidance of the worker, for so much depends upon his judgment and the nature of the work in hand. It is proposed, in this section, to deal with the general apparatus used by the "smith" and also to indicate, and describe, the more common terms and operations embraced under the heading "Forge Work."

In this work the first essentials are a forge, or hearth, and a fire, the latter to provide the necessary heat for the process and the former to hold the fire and to concentrate the heat on the work.

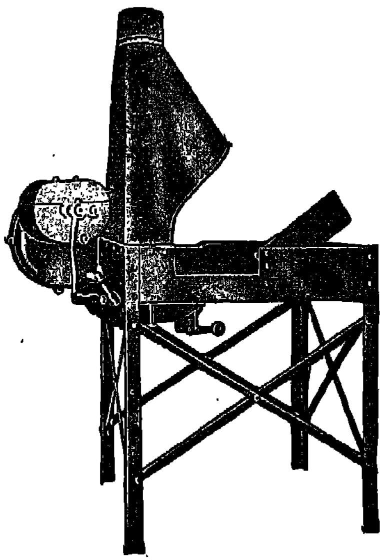
The Forge: Forges can be divided into two classes, the fixed and the portable types. The former are usually large and are the types generally used in blacksmith's shops, while the latter are found in workshops where the work done is of a smaller nature.

The main parts of a forge are the hearth, tuyere (pronounced twee-er), airpipe and fan. The larger types generally have a hood and flue for conveying the fumes and smoke away.

The blast is produced by the fan, and is passed along the air pipe through the tuyere into the hearth. Ordinarily, the air blast for a forge fire should have a pressure varying from 3 to 5 ounces per square inch.

The Fire: In forge work the fire is a very important factor as it provides the heat necessary for the production of work. The fire is started by cleaning the dead cinders and ashes away from the air holes and placing a piece of lighted waste or shavings over them. Blast is then

forced through the tuyere until these are reduced to glowing embers, coal or coke is then placed on them and the blast still continued. At first, dense volumes of white smoke rise from the hearth, but these give way to bright flames; after a further addition of coke the fire is soon ready for use.



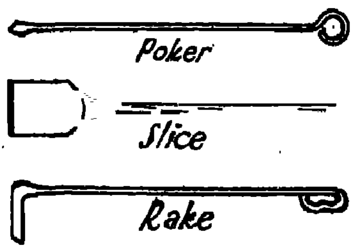
HAND FORGE.

The ideal fire is called a *reducing fire* and is one that consumes the whole of the oxygen supplied by the blast. This is obtained by maintaining a moderate and constant blast and by having a thick bed of fire through which the air must pass before reaching the metal. An excess of oxygen will cause the metal to oxidize, i.e., to form iron oxide, on the surface.

A fire that does not consume all of the oxygen supplied to it is called *an oxidizing fire*. This should be avoided as the metal tends to absorb the remaining oxygen, with the consequent forming of a loose scale of iron oxide on its surface.

Fuels: The fuel used must be as free as possible from impurities, particularly sulphur, coke being preferable to coal in this respect. When coal is used it should be broken up small and dampened to aid in the formation of coke. This dampened, or "green," coal is banked around the centre of the fire and as it cokes is gradually drawn into the centre.

Cleaning the Fire: Owing to the accumulation of clinker (slag) and dirt over the air holes, it will be found necessary to "clean" the fire every now and then, otherwise



FIRE IRONS.

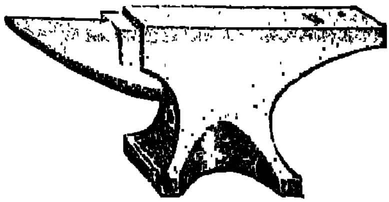
the free flow of blast will be obstructed. The tools used for this purpose and for opening or lifting up the fire are the poker, shovel or slice and the scraper or rake, the three being referred to as fire irons.

FORGE WORK TOOLS: The following are the tools used most frequently in forging operations :—

1. Anvil.
2. Tongs.
3. Hammers.
4. Cutting Tools.
5. Swages.
6. Fullers.
7. Set Hammers and Flatter.
8. Punches.

1. **The Anvil:** is made of mild steel with a cast steel working face. It usually sits on an anvil stand to bring it to a more convenient height. It consists of three working parts—the beak, the block and the working face.

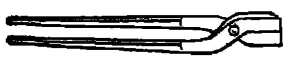
The Beak, or horn, is used for curved work, such as chain links, rings, etc.



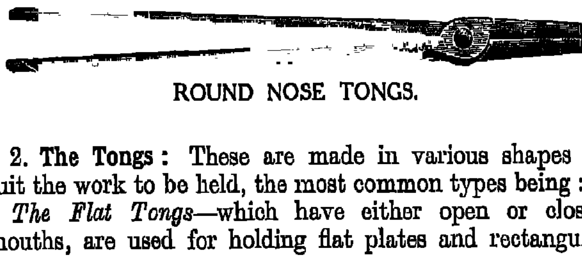
ANVIL.

The Block—is the small flat face between the beak and the working face. It is the part upon which metals are cut in order that the working face may not be damaged.

The Working Face—is used for general purposes, such as drawing down, flattening, welding, etc., and for making bends at its tail-end. The holes at the tail-end are to take the shanks of hardies, swages, etc.



FLAT NOSE TONGS.



ROUND NOSE TONGS.

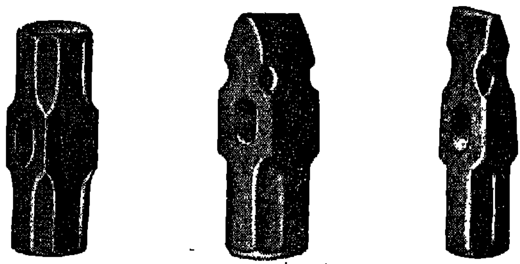
2. **The Tongs :** These are made in various shapes to suit the work to be held, the most common types being :—

The Flat Tongs—which have either open or closed mouths, are used for holding flat plates and rectangular bars.

The Rivet or *Pick-up Tongs*—for picking up and holding small round bars, rivets, etc.

The Straight Round Tongs—for grasping bars which are round, square or hexagonal in section.

The Bolt Tongs—for holding bolts, rivets, etc., the shape of the jaws allowing clearance for the head.

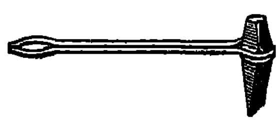


Double Faced. Straight Pane. Cross Pane.

BLACKSMITH'S SLEDGE HAMMERS.

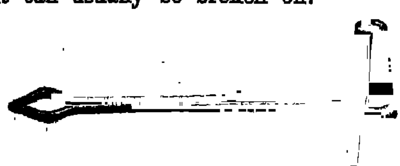
3. **The Hammers:** The hammers used in forge work are the $1\frac{1}{2}$ or 2lb. ball pane hammers, for light work, and the sledge hammers, in their various forms, for heavier work.

4. **The Cutting Tools:** These include the hot and cold sets and the hardie.



HOT SET.

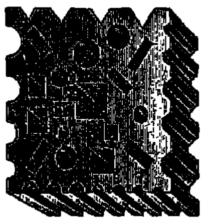
The Hot and Cold Sets are used for cutting off hot and cold metals respectively, the cold set being thicker towards the cutting edge than the hot set. The edge of these tools should not penetrate through the metal otherwise their cutting edges will be damaged on the hard surface of the anvil. After the metal has been cut partly through it can usually be broken off.



COLD SET.

The Hardie—a corruption of "hard edge," is used for light cutting and trimming. It fits into the hardie hole of the anvil, where it is used with the cutting edge uppermost, the metal being laid across it and struck with a hammer.

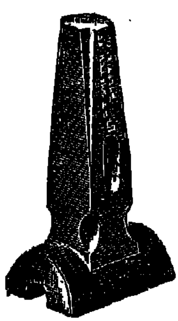
5. **The Swages:** These consist of the Swage Block and the Top and Bottom Swages.



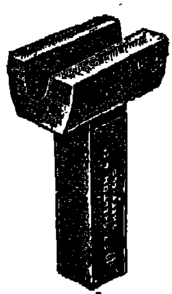
CAST IRON SWAGE BLOCK.

The Swage Block—is made of cast-iron and, as with the anvil, usually rests on a cast-iron stand, it has grooves of various forms and sizes running across its edges and is used for finishing off cylindrical, hexagonal or other forms, after they have been roughed-up on the anvil. The square and round holes on the surface are used for forming heads and bending.

The Top Swage—is used in conjunction with the swage block and bottom swage for rounding and finishing off cylindrical work.

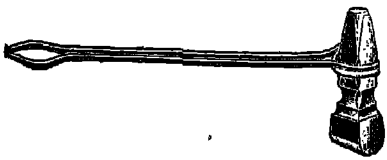


TOP SWAGE.

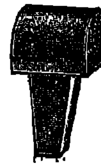


BOTTOM SWAGE.

The Bottom Swage—is fitted into the hardie hole of the anvil and is used, in conjunction with the top swage, for smoothing drawn-down and round work.



TOP FULLER.

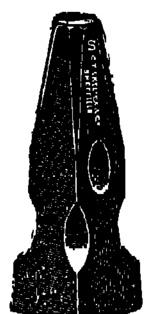


BOTTOM FULLER.

6. **The Fullers :** *The Top and Bottom Fullers* are used for forming grooves and hollows and for spreading metals. They are also used for finishing-up corners. The two fullers are often used in conjunction, the bottom fuller fitting into the hardie hole of the anvil.

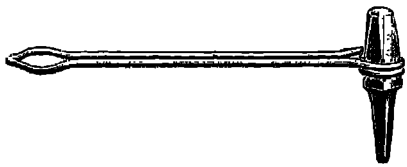
7. **Set Hammers :** The set hammers are used for drawing-down and reducing metals ; the square-edged type being used for producing sharp angles when forming shoulders.

FLATTER.



SET HAMMER

The Flatter, or *Flattener*—is also used for drawing-down and reducing metals and for finishing-off flat surfaces after they have been roughly shaped on the anvil by means of the hand or sledge hammers.



ROD PUNCH.

8. **Punches**: are used for cutting holes in red hot metals, of practically any desired shape or size.

The hot and cold sets, top swage and fuller, set hammers, flatters and punches are fitted with handles and do their *work by being held on to the metal and struck with the* sledge hammer.

FORGE WORK, although there are very many operations performed in the process of forging metals, the main ones may, for purposes of convenience, be divided into two classes, primary and secondary.

Primary Operations include those that bring about a change in the shape or form of the metal being worked. They are :—

1. *Bending*, the forming or turning of a piece of metal from the straight to an angular, or curved, form, *e.g.*, eye bolts and hooks.

2. *Drawing-down*, the reducing of the sectional dimensions of the metal with a corresponding increase in length and breadth, *e.g.*, chisels and centre punches.

3. *Upsetting*, or *Jumping-up*, the increasing of the thickness of a piece of metal by decreasing its length, *e.g.*, rivet and bolt heads.

4. *Welding*, the joining of two pieces of metal into one by heating them to a welding heat and then hammering, or pressing, them together.

Secondary Operations include such operations as the punching of holes, the cutting-off of lengths and the removal of surplus material; also the annealing, hardening, tempering and case-hardening of metals. These latter three have already been dealt with under "Heat Treatment of Metals," and so will not be considered further.

Before, however, discussing the above operations in detail, it might be as well to mention the various "heats" and fluxes used in forging, and their value in the production of work by these operations.

Heats: The different degrees of heat commonly used in the various forge work operations are:—

1. *Low Red Heat* (blood-red): When the redness of the metal is just noticeable in ordinary daylight, this is the heat most suitable for forging and hardening of tool (carbon) steel.

2. *Bright Red Heat* (cherry-red): When the metal shows a bright red that can be readily seen and a filmy grey scale appears on the surface, it is the heat used for bending mild steel and wrought-iron.

3. *White Heat*: When the metal is almost completely white in appearance, this is the degree necessary for the drawing-down and upsetting of wrought-iron and mild steel.

4. *Welding Heat*—is the stage following that of white heat and is the degree where the metal is just beginning to assume a fluid state. This heat is attained at a temperature of about 2,400° F. for wrought-iron, and 2,000° F. for mild steel. It is recognised by a rising of bluish-white sparks from the fire. The metal will "burn" if heated beyond this point.

The following table gives the approximate temperatures of the chief heats used in forge work:—

COLOUR	DEGREES CENTIGRADE	DEGREES FAHRENHEIT
Red Heat: Visible in the dark	400	752
Red Heat: Visible in the daylight	525	975
Dark Red	700	1,292
Cherry Red	900	1,652
Bright Cherry Red ...	1,000	1,832
Orange-Yellow	1,200	2,192
Yellow-White...	1,300	2,372
White Welding Heat ...	1,400	2,552
Brilliant White	1,500	2,732
Dazzling or Bluish White	1,600	2,912

If the metals are "burnt," or overheated, they develop a rough spongy appearance, become brittle, and are likely to crumble when hammered. After the removal of the metal from the fire, the blast should be kept on, for, if the fire is allowed to cool, the metal will burn upon being replaced. Once the metal has burned it is of no further use for welding.

When tool or carbon steel is being heated for forging purposes it should not be heated more often than necessary and then should be heated gradually, otherwise it will be rendered useless. Tool steel should not be heated to a higher temperature than that of a bright red heat, as overheating tends to reduce the carbon content, particularly near the surface, causing uneven hardening of the metal, thereby making it unreliable.

Fluxes—are used in the process of forging to assist in the welding of metals. Although welding can be accomplished without the aid of a flux, it is generally used to prevent oxidization, for the forming of a scale on the metal will lead to a defective weld. Wrought-iron can be heated to a temperature high enough to melt the oxide, which is then forced out by the hammer blows, but steel, particularly tool steel, would burn before this high temperature is reached, so, in this case, it is necessary to resort to the use of a flux.

The fluxes used for this purpose are fine, clean sand, borax, or a mixture of 2 parts burnt borax and 1 part sal-ammoniac, all having a melting point below the welding temperature of the work. They are sprinkled on to the heated ends of the metals when these have reached a yellow heat.

A flux serves three purposes :—

(a) It melts, and covers the heating surfaces, so protecting them from oxidization.

(b) It helps to dissolve any oxides already formed.

(c) The oxide melts at a lower temperature when combined with the flux and so flows away from the surface of the metal before welding heat is reached.

OPERATIONS.

1. **Bending**—may be divided into two classes, curves and angles, and is usually performed with the metal at bright red heat. Curves and circles are formed by bending the metal round the beak of the anvil, care being taken to hit the metal clear, or in front, of the anvil and not immediately above it, as the latter tends to alter the sectional form of the material. Angles are more difficult to form than curves, owing to the tendency of the metal to thin out and buckle slightly at the bend. This can be overcome to some extent by heating the metal to a temperature between bright red and white heat and forging the bend as quickly as possible.

2. **Drawing-down**—may mean the reducing of a metal in size without altering the sectional form, or may be the spreading and tapering of the metal. The easiest form of drawing-down is that of reducing a circular bar to a smaller diameter. This is done by heating the metal to the required temperature and then hammering it quickly on the anvil, at the same time keeping it as round as possible by turning it a little after each blow and then finishing it off with a swage. The tapering of a chisel, or a centre punch, is a good example of the drawing-down of a metal from the original section.

3. **Upsetting, or Jumping Up**: When it is desired to thicken a piece of metal at its end, or at some particular

part of its length, the process used is known as upsetting. To upset a bar at its end, the end is heated to a white heat and then jumped, or "bounced," on the anvil face by holding the bar between the hands, or it may be laid across the anvil face and the end struck with a hammer.

When the bar is to be upset at some place other than at the ends, it is heated to a white heat at that place only, the remainder of the length being kept cool by pouring water over it. The bar is then struck or hammered, as described above, when the metal will bulge at the place where it has been softened by heat.

In the making of a bolt, or rivet head, the end of the metal is first upset in the usual manner. When sufficient metal has been upset to form the head, the upset part is reheated and the cold end passed through the hole in the heading tool, which is then placed on the anvil with the body of the bolt passing through the hardie hole. The upset part is hammered down to the required thickness, taken from the heading tool and shaped with the hammer on the anvil to the required square section.

As upsetting sometimes tends to separate the fibres, it is advisable to guard against this by bringing the metal, in its final heat, up to welding temperature, when, by hammering a little, the loose fibres will be again united.

4. **Welding:** In this process two pieces of wrought-iron or mild steel are heated to a welding heat, i.e., until they become soft and plastic and will readily unite when one is hammered or pressed against the other.

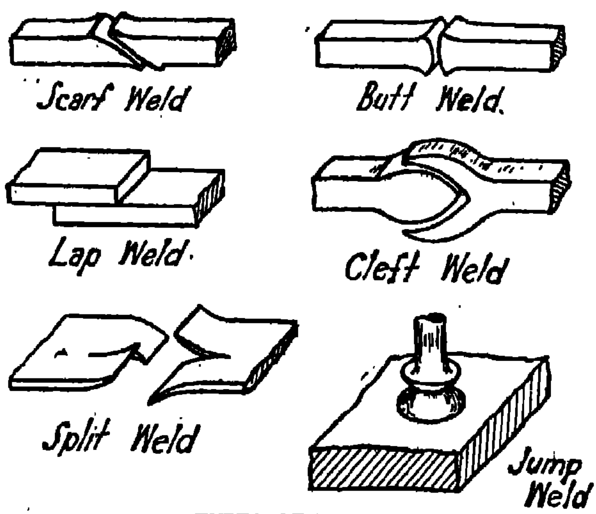
Punching: In forge work, holes, of practically any desired shape or size, may be punched in metals while red hot. They are formed by working through from both sides of the metal, the second side being punched over the round or hardie hole in the anvil.

Cutting—is generally done, in forge work, with the hot and cold sets, the former being used for cutting hot metals and the latter for cold. It is usually only necessary to cut a nick on opposite sides of the bar to start the

fracture, which is completed by striking the bar on the edge of the anvil. The hardie is another useful tool for cutting metals, particularly small bars; it has a square shank, which fits into the hardie hole of the anvil, and a chisel-like cutting edge. The metal to be cut is laid across this edge and then struck with a hammer.

CLASSES OF WELDS: Welds are classified according to the manner in which the pieces to be joined are fitted together. The most common welds in hand forging are:—

(a) Scarf Weld.
(b) Butt Weld.
(c) Lap Weld.
(d) Cleft Weld.
(e) Split Weld.
(f) Jump Weld.



TYPES OF WELDS.

(a) *The Scarf Weld*—is where the two pieces to be joined are thinned down, but with a slight bump in the centre, so that the centre will unite first and the slag be forced out as the metals come together.

(b) *The Butt Weld*: In this type of weld the pieces to be joined are generally upset a little and then are welded by hammering at the ends; as this tends to upset the joint still more, this type, in the case of round materials, is usually finished to the right diameter by swaging.

(c) *The Lap Weld*—has the two pieces to be joined laid face to face. When the faces are flat, the hammering is commenced in the centre and worked towards the edges, for the purpose of squeezing out the slag from the joint.

(d) *The Cleft Weld*: This type of weld is used where great strength is required. Before being joined, both pieces are first upset, whereupon one piece is split open, and the halves laid apart to form the cleft, and the other tapered to fit into it. In welding this joint the pieces are first hammered on the ends to make them unite, and then on the sides to close the joint, the slag being forced out as the sides close in.

(e) *The Split Weld*—is somewhat similar to the cleft weld, but is used for joining thin metals. The pieces are scarfed and split to fit into each other. They are heated separately to a red heat, placed together and the splits are closed down, then reheated to a welding heat and finally hammered together.

(f) *The Jump Weld*—is the form of weld used for joining a rod to a flat plate. The rod is upset and rounded to fit into a corresponding depression made in the plate. The surfaces must be so formed that, when brought together, the bottoms will unite first and the slag be squeezed out as the rod is forced into position.

SUMMARY.

FORGING—is the process of shaping and joining iron and steel by hammering, or pressing, under the influence of heat.

The first essentials of forge work equipment are the forge and the fire.

The Forge: This consists of the hearth, tuyere, air-pipe and fan. The air is produced by the fan, passed along the air-pipe, through the tuyere and so into the hearth.

The Fire: Provides the heat necessary for the production of work. The best type of fire is the reducing fire, which is one that consumes the whole of the oxygen supplied by the blast, thus keeping the metal free from oxides. The fire should also be cleaned when necessary to keep it free from dirt and clinker.

Fuels: These must be free from impurities, such as sulphur, coke being preferable to coal for this reason. When coal is used it must be broken into small pieces, damped and banked around the fire, into which it is drawn as it turns into coke.

Forge Work Tools.

The Anvil is made of mild steel and consists of three working parts, the beak, block and cast steel working face; it is used for the general forging and working of metals into various forms.

The Tongs are made in varying shapes to suit particular types of work; they are used for holding hot metals while they are being worked upon.

The Hammers which are used in forge work are the ball pane hand hammers for light work and the sledge hammers for heavy work.

The Cutting Tools: These include the hot and cold sets and the hardie, the former two for cutting hot and cold metals respectively, and the latter, whose shank fits into the hardie hole on the anvil, for cutting small bars.

The Forming Tools—such as the swages, fullers, set hammers and flatters—are used for the shaping and forming of metals in conjunction with the sledge hammer, anvil and swage block.

Punches—are used for punching holes of various shapes and sizes in red hot metals.

Forge Work: The main forge work operations are :—

1. *Bending*: This is the forming, or turning, of pieces of metal from the straight to curved or angular forms.

2. *Drawing-down*—is the reducing of a piece of metal by hammering or pressing, the result being a decrease in the thickness, with a corresponding increase in length and breadth.

3. *Upsetting*—is the increasing of the thickness of a piece of metal by decreasing its length.

4. *Welding*—is the joining of two pieces of metal, at a welding heat, by hammering or pressing. The most common forms of welds are :—

(a) Scarf Weld.
(b) Butt Weld.
(c) Lap Weld.
(d) Cleft Weld.
(e) Split Weld.
(f) Jump Weld.

Heats: The four main degrees of heat used for forge work operations are :—

Low Red Heat, where the redness is just visible in daylight.

Bright Red Heat, when the metal shows a very bright red with a film of grey scale on its surface.

White Heat, when the metal is almost completely white in appearance.

Welding Heat, the degree at which the metal begins to assume a fluid state.

The following table gives the heat colours, used in forge work, with their corresponding temperatures :—

COLOUR	TEMPERATURE (Degrees Centigrade)	TEMPERATURE (Degrees Fahrenheit)
Low Red Heat	525	975
Bright Red Heat	900	1,652
White Heat	1,300	2,372
Welding Heat	1,400	2,552

Fluxes—are used in forge work chiefly for the process of welding, and are usually fine sand or borax, their function being to protect the metals being heated from oxidation, to dissolve oxides already formed and to make the oxides more fluid in order that they may flow more readily from the surface of the work.

Questions :

1. What is meant by forging ?
2. What is the difference between a reducing and an oxidizing fire ?
3. Describe and state the uses of four forge work tools.
4. Give the names and approximate temperatures of the chief heats used in forging metals.
5. Name and describe two primary forging operations.

METAL WORK

MOULDING AND CASTING.

History: The moulding and casting of metals or "Founding" is of great antiquity. The important part it plays in the engineering industry of to-day is often overlooked as the attention is focussed more on the finished product than on the process.

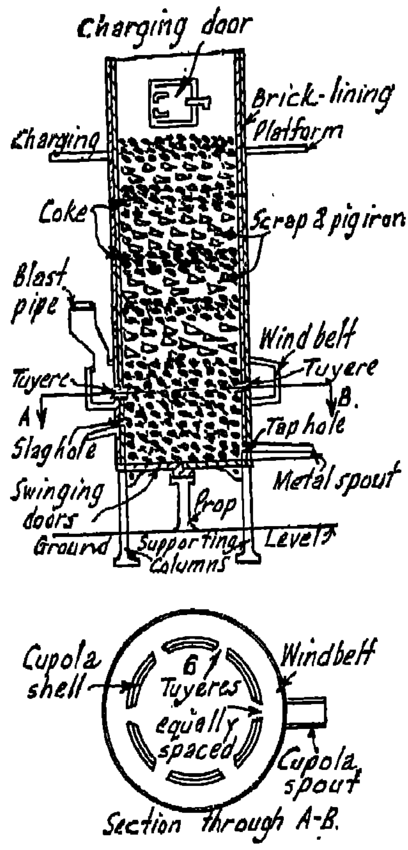
There is evidence that castings were made by the Egyptians as early as 2000 B.C. One of the best examples of ancient casting is that of the pillars of King Solomon's Temple. These were cast in bronze and were said to have been 27 feet long, 5 feet 9 inches in diameter, with a thickness of 5 inches. When one considers the amount of metal required to make each pillar it must be admitted that the artisans who moulded and cast them must have been skilled craftsmen.

The casting of bells was also practised in ancient times; there are many records of golden as well as bronze bells being used in temples for religious ceremonies. There is evidence also of bells being cast in England in 400 A.D. The largest bell in the world was cast in Russia in 1730. It weighs 193 tons, is 21 feet high, 21 feet in diameter with a thickness of metal of 23 inches.

Application: In the industrial and mechanical world of to-day the application of moulding and casting plays a greater part than is often realised. By far the greater part of mechanical construction is composed of castings either large or small and the production of the moulds necessary to make them calls for considerable thought and skill.

Metals: The metals used for making castings are:— (a) Iron, (b) Steel, (c) Brass and other non-ferrous metals.

(a) **Iron** is the metal most frequently used. It is melted in a furnace called a cupola.



FOUNDRY CUPOLA.

The Cupola is somewhat similar in principle to the blast furnace. It consists of a cylindrical shell made of boiler-plate lined with refractory fire bricks. It has an opening for charging and a tap-hole at the lowest level to enable

the molten metal to be drawn off. There are swinging doors at the bottom which allow the furnace to be thoroughly cleaned after each period of melting. The forced air or blast enters the furnace through the tuyeres. These vary in number and are situated in a wind-belt, placed around the body of the cupola above the tap-hole.

Cupolas are generally relit daily and range in capacity from 5 tons to 20 tons of iron. The average foundry cupola will produce molten metal from the solid in about 30 minutes and will reduce about 6 tons of iron in approximately 4 hours.

The Charge in the cupola consists of pig-iron, scrap iron and coke, additional coke and iron being added through the charging hole as the lower charges are melted and drawn off through the tap-hole.

A certain amount of slag is produced from the ash of the coke, the dirt and the impurities in the pig-iron. This is removed through the slag-hole which is placed at a level higher than that of the tap-hole.

Preparation : In preparing the cupola for the charge the swinging doors at the bottom are closed and a sand bottom or bed made up on them. This sand bottom slopes towards the tap-hole and is made through an opening in the side of the shell, which is closed with a plate when the bottom is finished.

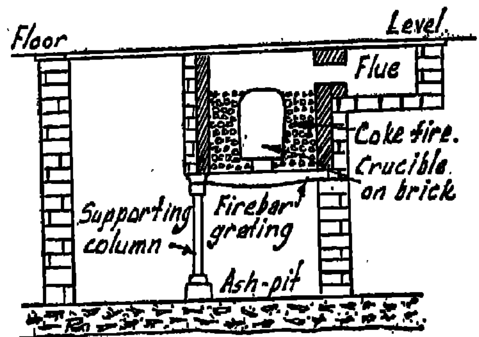
Tapping : The tap-hole is closed until sufficient molten metal has accumulated at the bottom of the furnace and the slag on top will flow out of the slag-hole.

The tap-hole is then opened and the molten metal allowed to run into a ladle, after which the tap-hole is closed again with wet clay. The ladle with the molten metal is carried to the moulds either by crane or by hand.

(b) **Steel :** Steel castings are used where great strength is necessary. When large quantities of steel are required the steel is melted in the open-hearth furnace as described in a previous chapter, also in the electric and crucible furnaces.

(c) **Brass and Non-ferrous Metals**: Brass is usually melted in a crucible furnace, coke being used as fuel but with a natural draught instead of a forced one.

The Crucibles used in the brass-furnace are moulded of fire-clay and powdered graphite and will withstand very high temperatures. They range in capacity from 2 pounds to 100 pounds of metal.



BRASS FURNACE

Operating the Furnace: The crucible is placed in the furnace on a brick on the fire-bar grating of the furnace and the charge placed in the crucible. Coke is then packed around it, a coke fire having been previously lit in the furnace. As the coke burns away, more is added until the charge is melted. The crucible is then lifted out of the furnace by means of shaped tongs and a swinging arm mounted over the furnace and then carried to the moulds. Most other non-ferrous metals are also melted in the brass furnace in crucibles.

Materials Used: The materials used in forming the moulds may be divided into :—

(a) The sand used to ram around the pattern; and
(b) The dressing applied to the surface of the mould before the metal is poured into it.

(a) **Sand:** The sand used will depend upon the metal being used, because different metals require different qualities in the sand.

Iron: The sand used for iron must be able to withstand damp, the impact of the molten metal, and be porous enough to permit the passage of gases generated within the sand. It is united or bonded by mixing a small quantity of very strong, clayey loam with larger quantities of burnt sand from previous moulds. Coal dust is added to the sand used next to the face of the pattern to ensure a smooth surface to the casting, this special sand being known as facing sand.

Steel: The sand for steel moulds must be highly refractory to withstand the high temperature of steel and at the same time be porous enough to enable the gases to escape. Sandstone is the ideal sand for steel moulds as it consists of nearly 98% silica, a very refractory material. Sandstone itself has no bond or cohesion, therefore a mixture of molasses and water is added to the crushed sandstone to provide the necessary bond.

Brass: The sand used for non-ferrous castings need not possess the strength of the sand for iron or the heat resisting qualities of steel sand, but it must have a fine texture and be porous. The fine texture is necessary because the sand has to take and retain the very fine designs of the pattern. The best brass sands are those which have been washed away from beds of heavier and stronger sands. These alluvial deposits contain only the finest grains with a small proportion of bonding element.

(b) **Dressing for Mould Surfaces:** It is necessary to apply a dressing to the surface of the mould otherwise the surface or skin of the finished casting would be very rough. The dressing provides a protection between the molten metal flowing into the mould and the sand surface of the mould. It does this by causing a thin layer of gas to form between the metal and the sand.

As with other branches of moulding the dressing used will depend upon the metal being poured into the mould, *e.g.* :—

Iron Moulds : The dressing for iron moulds is usually a compound made with a graphite base and is either dusted on to the surface of the mould through a piece of coarse hessian or is made into a paste with water and painted on to the sand with a brush.

Steel Moulds : The dressing for steel moulds is called silica paint and is made by mixing finely ground silica with water and just sufficient china clay to make it stick to the sand.

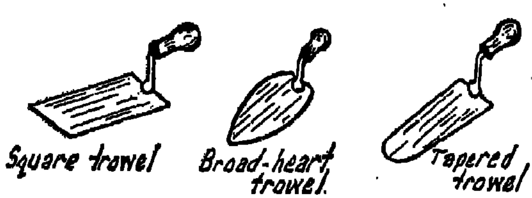
Brass and Non-ferrous Moulds : The dressing for brass and similar moulds is the same as for iron moulds except that for dry sand moulds, flour is added to the graphite base.

Tools : The tools used for moulding may be divided into :—

(a) Moulding tools and

(b) Ramming tools.

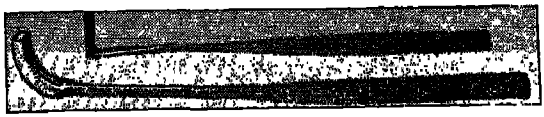
(a) **Moulding Tools** : The tools used by a moulder while not being elaborate are many, each serving a very definite purpose.



TYPES OF TROWELS.

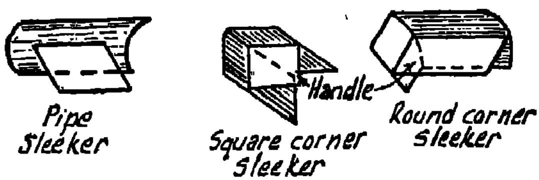
The main tools are the *trowels*. These are made in many different shapes and are used for making the joint of the mould and for patching up broken portions of the mould.

The Cleaners are used for cleaning out deep sections of moulds. They are made in sizes ranging from ¼-inch up to 1½-inch wide.



TYPES OF CLEANERS.

The Smoothers or *sleekers* are used for the varying shapes and curves of the mould.

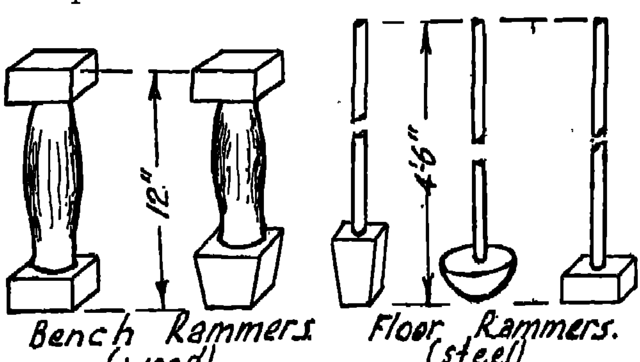


TYPES OF SLEEKERS.

(b) **Ramming Tools :** The tools used for ramming the moulds are divided into :—

(1) Floor rammers ; and (2) Bench rammers.

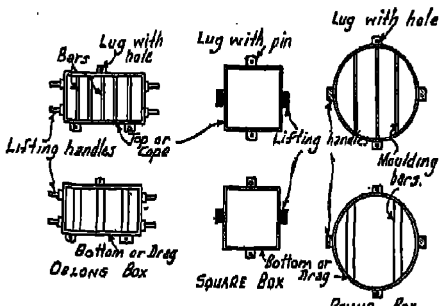
(1) *Floor rammers* are used when the moulds are rammed up either on or in the floor of the foundry.



(2) *Bench rammers* are used mostly in the brass foundry where the greater proportion of the moulds are rammed up in small boxes on a bench and then placed on the floor.

Boxes: Unless the mould being made is very large it is made within the confines of a moulding box.

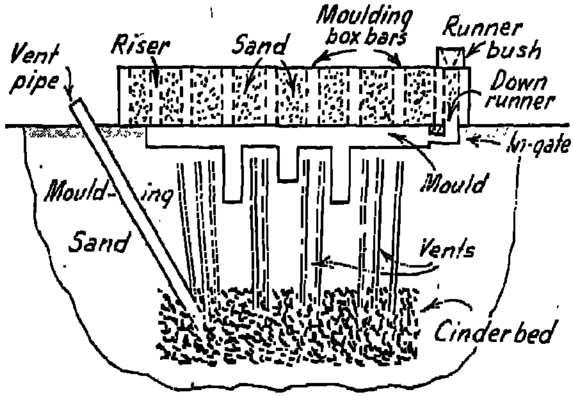
Moulding boxes are generally made of cast-iron. They are made by the moulder from wooden patterns and are divided into parts in order to allow the mould to be separated or jointed for the convenience of withdrawing the pattern and introducing the core.



TYPES OF MOULDING BOXES

These parts are called the top or cope and the bottom or drag and may be round, square or oblong in shape. Moulding boxes are fitted with lifting handles; the bottom part also has a lug on each end fitted with a fixed pin which fits into a hole in the corresponding lug at each end of the top part. This ensures that the two boxes are put together in exactly the same positions as when they were rammed up.

When the mould is too large to be made in a box, it is rammed up in a hole in the floor of the foundry and a large iron box placed over it.



METHOD OF MOULDING IN FLOOR

Divisions of Moulding : Moulding may be divided into two sections, viz. : (a) Green Sand ; and (b) Dry Sand.

(a) **Green Sand Moulding :** This term is applied when the moulds are poured with the sand in the same condition as when rammed up, i.e., damp.

The procedure adopted in making a simple green-sand mould is as follows :—

Step 1.—See that the sand to be used is in the proper condition, i.e., it should be damp enough to retain the shape of the pattern after it has been withdrawn, but it must not be too damp.

Step 2.—The pattern to be made is rammed up in the bottom half of the moulding box. This is done by placing one-half of the pattern on a flat board, placing the bottom half of the box over the pattern and filling up with sand. This sand is rammed with a floor rammer, until the box is full.

Step 3.—The box is then turned over ; the joint made and the other half of the pattern placed in position. Parting sand is sprinkled on the joint and the top box placed in position and rammed up with sand.

Step 4.—The top box is lifted off, the pattern withdrawn from the sand, the mould patched up if necessary, surface dressing applied and the necessary provision made for pouring the metal into the mould.

Step 5.—Replace the top box on the bottom box. The mould is now ready for casting without any further treatment.

(b) **Dry Sand Moulding**: The making of a dry sand mould differs little from the practice adopted in green sand except in the finishing stage. The sand used should be no wetter than for a green sand mould but should be stronger, the reason being that dry sand moulds are used when the amount of iron required is considerably greater than would be used in a green sand mould.

The mould dressing for dry sand is made by mixing powdered graphite "plumbago," into a paste with water and thinning out with more water if necessary. A little clay water or thin molasses water may be added to make it stick to the surface of the mould. This dressing is applied to the mould with a brush or a swab made from a piece of teased out cotton or hemp rope.

After the dressing has been applied the whole mould is placed in a drying stove and the moisture in the sand dried out. If the mould is made in the foundry floor it is dried out by placing a gas jet inside the mould.

Core Making: The purpose of a core is to allow a hole to be made in a casting. The making of a core is very similar to the dry-sand moulding process because it is rammed-up wet, painted with a wet facing and afterwards dried out in a core oven.

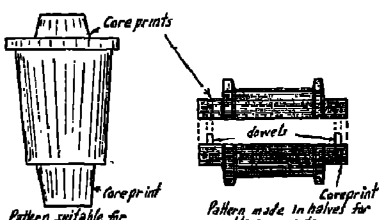
Cores need to be—(a) Strong.
(b) Porous—when dry.

(a) A core needs to be strong because quite frequently it is almost completely surrounded by metal, therefore the sand of which it is mostly composed must contain

some binding properties to hold or knit it closely together. Usually new moulding loam is quite satisfactory, but to assist in this respect molasses or treacle is mixed with water and worked into the sand before shaping the core.

(b) A core needs to be porous so that it will allow the gases to escape freely and so that it can be readily broken up and cleaned out of the casting after it has solidified. The ingredient used to achieve this aim is sawdust. The sawdust takes up moisture in the mixing and swells with the result that when the moisture is driven off in the oven an open structure is left within the core. Also, later on the heat of the molten metal burns away the sawdust, allowing the core to be cleaned out more easily.

Patterns : The patterns used for moulding play a very important part and must be well and carefully made, as a badly made pattern can cause a lot of trouble. For this reason the patternmaker should have a general idea of the principles of moulding. The patterns are always, in the first place, made of wood, preferably redwood, because it is straight-grained and not liable to shrink or twist.



TYPICAL PATTERNS

When a pattern is likely to be subjected to hard and constant wear, it is made of iron, brass, or aluminium, from the original wooden pattern.

The pattern-maker must allow a taper on the pattern to enable it to be withdrawn from the mould without breaking the sides of the mould.

Shrinkage and Contraction: As metals pass from the molten to the solid state a change takes place, called shrinkage. Contraction is the term applied to the change of form which takes place after shrinkage, and which is effected after the casting has solidified. This contraction must be allowed for by the patternmaker when making the pattern. The contraction for iron is about $\frac{1}{8}$-inch per foot, while that of steel is likely to be greater depending upon the size of the casting.

The moulder guards against the fracture of a casting during shrinkage by various means, *e.g.* :—

(i) In steel this precaution consists of forming ribs at various intervals thus joining the thinner parts to the larger body of the casting. These ribs will fracture before the main casting and can be cut off later if necessary by means of the oxy-acetylene torch.

(ii) In cast-iron the same effect is achieved by the moulder rounding the square angle made by the junction of a thick and thin portion. This is done by cutting away the sharp edges of the mould with a sharp trowel. The effect of this rounding or "filleting" is to make the corner stronger by assisting the more regular crystallisation of the metal.

Ramming: Ramming of a mould is where the skill and experience of a moulder is tested, for upon the ramming of the mould will depend the success of the casting.

A mould that is rammed soft will produce a casting that is misshapen and swollen, and if rammed too hard the metal will not lie against the surface of the mould. This is due to the resistance offered by the hard surface to the escape of gases formed in the sand by the molten metal. The effect of this resistance is to cause the surface of the mould to break and form what is known as a "scab" upon the casting. The experience of the moulder will tell him that a deep mould must be rammed harder at the

bottom than at the top because the pressure there will be greater. The sand coming in direct contact with the pattern is not rammed but is compressed against the pattern by ramming the sand at the back of it.

Venting: When molten metal comes in contact with sand, gases are generated and although moulding sand is porous, it is necessary to assist the escape of these gases as well as any air from the mould. This operation is called venting, and it helps largely to guard against any mistakes the moulder may make when ramming the mould. The venting of a mould gives a definite outlet for the gases and allows the moulder to guide them in the direction most likely to give the best results.

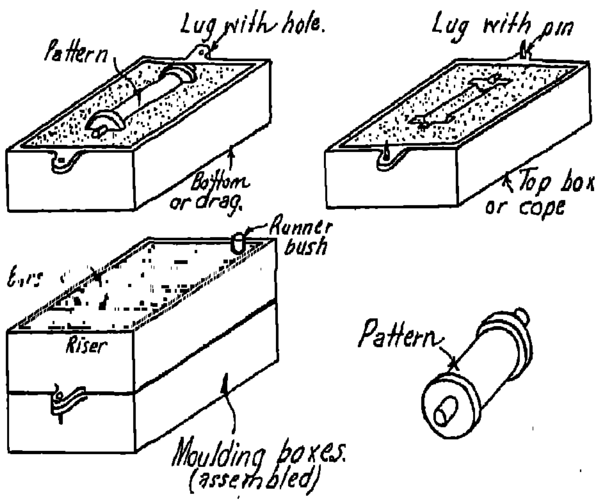
In small moulds a vent wire is forced into the sand surrounding the pattern before it is removed. On removing the wire a small tunnel or vent is left in the sand through which the gases, following the line of least resistance, escape. The vent wire is suitable for small work but in larger work special arrangements are necessary.

When the surface of the casting is large in comparison with its depth, or when gases are likely to be trapped and unable to find an outlet without passing through the liquid metal, a prepared bed of cinders is made beneath the mould. This collects the gases from under the casting. The outlet from the cinder bed is provided by the introduction of a piece of pipe from the bed to the outside of the moulding box.

Venting of cores is carried out in a similar manner; with small cores a vent wire is forced through the centre but with larger cores the centre of the core is made of coke or cinders which provides the necessary outlet for the gases.

Jointing: The joint of the mould is the level or surface between the top box and the bottom box. When a mould is rammed up, one portion of the pattern is usually rammed in the bottom box, and the remainder in the top, therefore some means of parting the sand in both boxes is necessary. The surface of the sand in the bottom box is made firm

and smooth by means of the trowel. Sea sand is then sprinkled over it so that when the top box is rammed this sand prevents the two surfaces sticking together. The making of the joint also ensures that the pattern can be withdrawn from the mould without breaking the edges.



Pouring the Metal: When the cupola is tapped the molten metal is drawn off into a ladle and thus carried to the mould. Depending on the size of the casting to be poured, these ladles vary in capacity from 25 lbs. to 15 tons, the former being carried by hand, the latter necessitating the use of a crane.

Gates, Runners and Risers: The means by which the metal enters the mould is through the down-gate into the in-gate and thence into the mould, the complete passage being referred to as the runner. The purpose of this runner is to deliver the metal into the mould in the shortest possible time and at the same time not cause any damage to it. It is necessary also that this runner be easily broken off later without damaging the casting.

Different types of castings require different types of in-gates, and the skill of the moulder is tested in ensuring that all these requirements are carried out.

The Riser is an opening from the inside of the mould to the outside, and its purpose is to relieve the pressure within the mould. The riser is placed on the thickest, and if possible, on the highest part of the casting, and is usually round. It is made by forcing a round tube through the sand after the mould is rammed up.

Brass Moulding : Although present day brass founding consists of making brass castings with a definite use in the engineering industry, the casting of statues in bronze has played a large part in the history of founding. There are many specimens preserved of Greek and Roman bronze statuary; these have very fine and clear-cut impressions. The means used by the ancients to obtain these impressions are not clear, but the results prove that they had a very sound knowledge of the art. The casting of bronze statuary in England was commenced about 1200 A.D., the statue of the Black Prince being among the earliest specimens.

The methods adopted to-day for brass moulding are similar to those used for iron, but the moulds are, to a greater extent, made on benches by the turn-over method. The sand used in a brass foundry is always somewhat finer in texture than that used for iron founding.

In making a mould for brass on a bench, the procedure is as follows :—

Step 1.—The moulder selects a box large enough to cover the pattern.

Step 2.—The bottom half of the box is placed over the bottom half of the pattern which is lying on a flat board; moulding sand is placed around and over the pattern and rammed with a bench rammer until the box is full.

Step 3.—The box is turned over and the joint made.

Step 4.—The top half of the pattern is placed in position and the top box put on.

Step 5.—The tube to form the down-gate is put in position and sand rammed into the box until it is full.

Step 6.—The top box is lifted off and the two halves of the pattern removed from the sand.

Step 7.—The in-gate is cut, any broken pieces of the mould mended, and then the mould dressing dusted on.

Step 8.—The top box is replaced, the pins and lugs on the box ensuring that the box goes back in exactly the same position.

Step 9.—The two boxes are carried from the bench and placed where the metal is to be poured.

The boxes are held together during casting by clamps placed over the two lugs or by weights laid on the top box.

Steel Moulding : The demand for strength combined with less weight has given an impetus to the production of steel castings.

The principles involved in steel founding do not differ greatly from those for iron, the difference being mainly that of the materials used.

Owing to the high melting point of steel the sand used must be very refractory or heat-resisting. This must also apply to the mould dressing.

Molten steel is not so fluid as iron and it solidifies more quickly, hence the gates and risers must be larger and the metal poured more quickly.

The design of a pattern for a steel casting must take into consideration the greater shrinkage and contraction of steel. The moulder must also make allowance for this shrinkage and contraction and by various means counteract them as far as possible.

Because most steel castings are large they are not rammed up entirely in the prepared steel moulding sand. A thickness of 2 inches or 3 inches of facing sand is placed against the pattern. This is backed with sand made by mixing burnt steel sand with a small amount of water.

This backing sand is rammed hard and so compresses the facing sand against the pattern. After the pattern has been removed, the mould is painted with silica paint and dried.

Owing to the excessive shrinkage and contraction most steel castings are annealed. This annealing is carried out in a specially constructed furnace. The casting is placed in this furnace and heated up to a temperature just below melting point. The temperature is held at this point for as long as 72 hours and then allowed to cool off slowly.

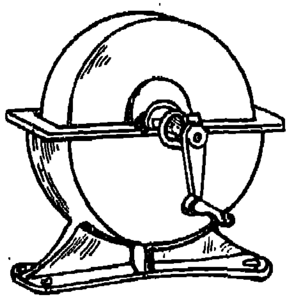
The metal left on the steel casting from the large gates and risers is removed by the oxy-acetylene torch.

Questions :

1. Name the principal metals used in foundry practice.
2. How are these metals melted ?
3. Name the materials used to form the moulds.
4. Name the divisions of Moulding and describe how they differ from one another.
5. Why is venting one of the most important operations in moulding ?

GRINDING AND SHARPENING.

GRINDSTONES—are natural sandstones used for grinding machinists' and carpenters' tools and for smoothing certain surfaces prior to polishing operations.



BENCH GRINDSTONE.

Using the Grindstone: When using a grindstone it should be turned towards the implement being ground, not away from it, and the edge of the tool should be kept level with, and parallel to, the axis or centre of the stone. Frequently stones are either bevelled or hollow on the surface, the former is caused by holding the tool being sharpened at an angle to the centre and the latter by grinding narrow tools in the middle of the stone, instead of moving them slowly from side to side; either defect makes it difficult to get a true, straight edge on a tool such as a plane iron. A good plan is to grind narrow blades on the edges of the stone. A can of water with a drip tap should be placed above a grindstone to allow water to drip steadily on to it as it revolves.

Care of the Stone: As grindstones are softer wet than dry, they should never be left standing with any part of the circumference in water, because, when the stone is used again, it will tend to wear away faster on the wet

side than on the dry, which means that it will soon lose its true circular form and will need reshaping. Then, again, wet stones are not as strong as dry, the soaking with water tending to reduce the tensile strength of the sandstone.

Speeds for Grindstones: The proper speed for a grindstone depends upon its use. For grinding carpenters' tools the peripheral speed should range from 500 to 600 feet per minute and for machine tools from 800 to 1,000 feet per minute, while for grinding surfaces, prior to polishing, they are run at much higher speeds. There is, of course, a maximum speed, which is limited by the strength of the stone.

The following table gives the approximate revolutions per minute for grindstones of varying diameters, corresponding to a peripheral speed of 3,400 feet per minute.

MAXIMUM SPEEDS FOR GRINDSTONES

DIAMETER OF STONE	REVOLUTIONS PER MINUTE	DIAMETER OF STONE	REVOLUTIONS PER MINUTE
3 ft.	365	5 ft. 6 ins....	196
3 ft. 6 ins. ...	308	6 ft.	180
4 ft.	270	6 ft. 6 ins....	166
4 ft. 6 ins. ...	240	7 ft.	154
5 ft.	216		

GRINDING WHEELS: Grindstones have been superseded almost entirely by grinding wheels. These are much harder and are able to withstand far greater strain than grindstones. This allows them to reduce metals much more rapidly. Grinding wheels are made artificially in a great variety of shapes and sizes. The abrasive materials or cutting agents used may be either natural or artificial, some of which are:—

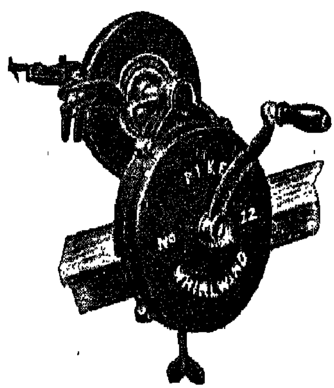
1. Natural abrasives $\begin{cases}\text{Corundum}\\\text{Emery}\end{cases}$

2. Artificial abrasives $\begin{cases}\text{Aloxite}\\\text{Alundum}\\\text{Carbolite}\\\text{Carborundum}\end{cases}$

Corundum and emery are tough, durable abrasives the cutting agent of each being crystalline aluminium oxide.

Alundum and aloxite are products of the electric furnace. They are abrasives of the aluminous group being produced from bauxite, a type of clay rich in alumina.

Carborundum and carbolite belong to the silicon-carbide group. They are made in the electric furnace from a mixture of coke and sand.



HAND GRINDING WHEEL.

Speeds: Grinding, or Emery wheels, as they are more commonly called, may be driven either by hand or power. The latter type should not be run at a speed exceeding 5,500 feet per minute, for rough grinding, or 6,000 feet per minute for precision work.

The following table gives the speeds of power-driven wheels up to 12 inches in diameter :—

DIAMETER OF WHEEL	4ins.	5ins.	6ins.	7ins.	8ins.	10ins.	12ins.
Revs. per minute for surface speed of 4,000 ft. per minute	3,820	3,056	2,546	2,183	1,190	1,529	1,773
Revs. per minute for surface speed of 5,000 ft. per minute	4,775	3,820	3,183	2,728	2,387	1,910	1,592

Grades : The " grade " of a grinding wheel is the strength or tenacity with which the abrasive or cutting particles are held in position by the bonding material. Grinding wheels are usually graded, from relative softness to hardness, by letters, as under :—

DEGREES OF RELATIVE HARDNESS

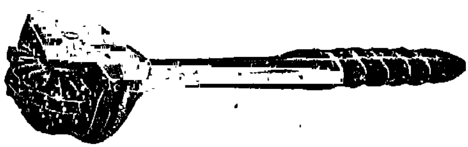
SOFT	MEDIUM SOFT	MEDIUM	MEDIUM HARD	HARD
E.	I.	M.	Q.	U.
F.	J.	N.	R.	
G.	K.	O.	S.	
H.	L.	P.	T.	

Grain : The relative coarseness or fineness of the wheels is referred to as the *grain* or "*grits*." This is defined by numbers, usually ranging from 10 to 80, advancing by fives. The numbers refer to the size of the grits used for making that particular wheel. For example, No. 40 would mean that the grains would pass through a sieve with meshes one-fortieth of an inch square, or with 1,600 meshes to the square inch.

It should be noted that the grades and "grits" of wheels are independent of each other, making it possible for one to obtain a wheel of any desired grade, combined with the degree of coarseness or fineness required, working, of course, within the limits of that particular make of wheel.

Care of Wheels: Grinding wheels should be kept true by frequent dressings with an emery wheel dresser, also the wheel rest should be adjusted as the wheel wears, so as to keep it always close up to the face. Heavy articles should be ground with great care, and grinding upon the sides of the wheel should be reduced to a minimum. The wheel should not be left standing in water or oil for any length of time.

Never attempt to grind lead on a grinding wheel as the metal will fill up the pores of the wheel and so render it useless for further work.



EMERY WHEEL DRESSER.

As with the grindstone, tools should be worked squarely across the face of the wheel, otherwise it will soon become grooved or misshapen. The tools should not be pressed too hard against the face as this will make them hot and will draw the temper from their edge.

Wheel Guards: All grinding wheels, particularly the power-driven types, should be guarded in order to protect the operator. Goggles should also be worn, when necessary, to protect the eyes from possible injury.

Oilstones—are small rectangular blocks of abrasive material, such as carborundum, and may be either natural or artificial in composition. They are obtainable in three grades, coarse, medium and fine. The coarse stones are used for sharpening large and very dull tools and for

COMBINATION OIL STONE.

general sharpening without regard to the fineness of the edge. The medium stones are used for sharpening tools for working leather, cloth and soft woods, etc. The fine stones are used for tools requiring a very fine, keen edge, such as those used by instrument and cabinetmakers.

Stones can be obtained with one medium and one coarse face, *thus giving a combination of two stones* in one.

OILSTONE SLIP.

Oilstone Slips are small tapered or bevelled stones used for internal sharpening on tools such as gouges.

Using the oilstone: When sharpening tools on an oilstone it is necessary to use either water or oil on the surface to keep the particles of metal out of the pores. The former is usually used on the coarser stones, but oil is invariably used on the finer types. As with the other grinding mediums, care should be taken not to make grooves or hollows in the surface. This can be avoided by drawing the tool more or less diagonally across the stone as the length is traversed. To prevent glazing, or "gumming up" the stone, the dirty oil should always be wiped off with a piece of clean cotton waste, as soon as

possible, after using the stone. This is very important, for if the oil is left on the stone it dries into the surface, carrying the metal particles with it.

Care of Oilstones: An oilstone should be kept clean and moist, for dryness tends to harden it. If it is to be kept in a dry place, a few drops of clean oil should be placed on the surface and the stone kept in a box with a tight-fitting cover.

Truing the Stone: When the face of an oilstone becomes worn it can be trued by placing some fine emery powder, mixed with a little water, on a hard plane surface and then rubbing the stone until it is again true.

Questions:

1. What are grindstones?
2. What special care must be taken of them?
3. Why are grinding wheels preferred to grindstones?
4. What causes grooving or bevelling on the faces of grindstones and grinding wheels. How is this avoided?
5. Describe an oilstone and state its use.

CONSTRUCTION.

In the making of any model or piece of work it is advisable to so order the work that each step in the construction follows naturally upon the preceding one, making the process progressive throughout. It will be found that most pieces of work lend themselves, more or less readily, to construction under the following steps or headings :—

1. Preparation.
2. Marking-off.
3. Operations.
4. Assembling.
5. Finishing or cleaning.

1. **Preparation**—covers the following points :—

   (a) Obtaining the tools and materials necessary.
   (b) Checking materials for size, etc.
   (c) Coating, if necessary, the surface of the material with a suitable marking medium.

2. **Marking out**—is the setting out of lines, curves, etc., from the blue-print on to the surface of the work for guidance purposes during operations.

3. **Operations.**—mean the shaping and forming of the separate pieces of work by cutting, filing, turning, planing, etc.

4. **Assembling**—by this is meant the placing together of the several pieces or parts of the work that make up the whole.

5. **Finishing** or **Cleaning**—is necessary to impart a finished appearance to a piece of work. This is done by polishing with mediums such as files, emery cloth, metal polish, etc.

Note : It must be pointed out that these steps are merely suggestive and that rigid adherence to them is not essential, nor, indeed, always practicable. For example, it may be necessary to assemble portion of the whole before

certain parts can be marked off; again, it may be easier to finish or polish a unit before it becomes part of the whole.

The following suggests a method of making a pair of calipers from mild and tool steel, also a small scoop from tinplate, with the descriptions set out, and illustrated, in accordance with the above five steps:—

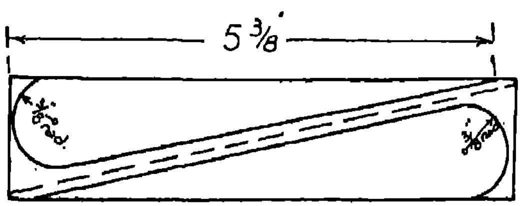
1. *MAKING A PAIR OF CALIPERS.*

Step 1.—PREPARATION.

(a) Obtain material required:—
Spring steel (for legs), 1 piece $\frac{3}{4}$ in. × $\frac{1}{16}$ in. × 6 ins.
Mild steel (for washers), 2 pieces $\frac{3}{4}$ in. diameter × $\frac{1}{8}$ in. thick.
Mild steel (for rivet), 1 piece $\frac{3}{16}$ in. diameter × $\frac{5}{8}$ in. long.

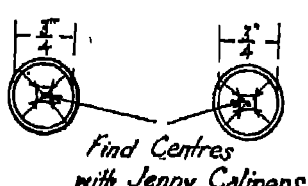
(b) Place the piece of spring steel and the washer discs on the filing board and clean one face of each with a file.

(c) Coat the cleaned surface with copper sulphate solution preparatory to marking.



Step 2.—MARKING-OFF.

(a) Draw a diagonal across the face of the metal and mark out the legs, as shown, from the blue-print.



(b) Find the centres of the washer discs with the Jenny calipers. Centre punch and scribe $\frac{3}{4}$ inch diameter circle on each.

Step 3.—OPERATIONS.

The Legs.

(a) Cut along the diagonal with the flat chisel.

(b) Drill the $\frac{3}{16}$ inch holes in each leg.

(c) Place together in vice with rivet through holes and file to shape.

(d) Curve and shape the legs by heating to redness.

1. *Jenny Calipers* : Curve one leg with a light hammer to a small radius and sharpen the other to a point.

2. *Inside Calipers* : Curve both legs to a small radius.

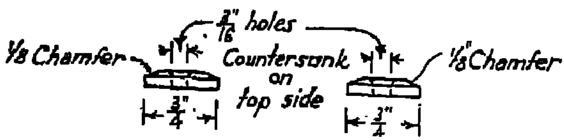
3. *Outside Calipers* : Curve both legs round a suitable bar to a radius of $1\frac{3}{4}$ inches.

(e) Place the legs on the filing board and clean up the faces by cross-filing and draw-filing.

The Washers :

(a) Drill $\frac{3}{16}$ inch holes in washer discs and counter-sink one side of each.

(b) Clean up both faces of each disc with a file.



(c) Place together on mandrel and reduce to correct diameter, testing with outside calipers. Form chamfers on the same side as counter-sinks.

Step 4.—ASSEMBLING.

Place legs and washers together and rivet carefully with $\frac{3}{16}$ inch rivet.

Note : After riveting the Jenny calipers, harden and temper the point of the divider leg to a light straw.

Step 5.—FINISHING.

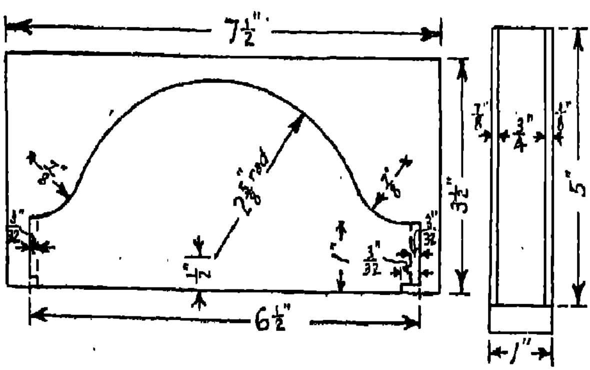
Secure the calipers to the filing board and "clean up" with dry emery cloth and finally polish with smooth emery cloth and oil.

LIST OF TOOLS USED: Rule, scriber, centre-punch, dividers, cold chisel, ball pane hammer, hacksaw, $\frac{3}{16}$ inch drill, counter-sink, drilling machine, mandrel, outside and Jenny calipers, files (1-10 inch flat, second cut; 1-8 inch flat, smooth), filing board and emery cloth.

MAKING A SMALL SCOOP.

Step 1.—PREPARATION.

(a) Obtain materials required—
Tinplate (for body), 1 piece $7\frac{1}{2}$ ins. × $3\frac{1}{2}$ ins.
Tinplate (for handle), 1 piece 5 ins. × 1 in.
Tinplate (for back piece), 1 piece $2\frac{1}{2}$ ins. × $2\frac{1}{2}$ ins.

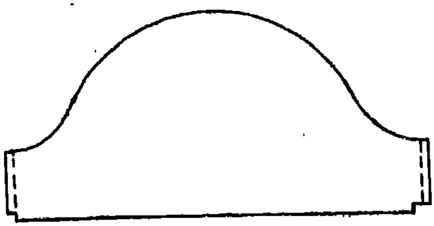


Step 2.—MARKING OFF.

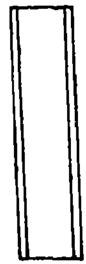
Set out the development of the body of the scoop, also the handle strip, from the blue-print, as shown.

Step 3.—OPERATIONS.

(a) Cut out the development of the body of the scoop, also the handle, using the straight or curved snips as required.

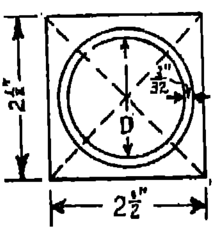


Body of Scoop



Handle

(b) Bend the body piece to circular form, using a flat-faced mallet and a pipe of suitable diameter. Close and solder the joint.



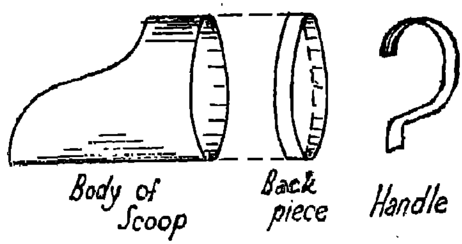
D = diameter — To be obtained by measuring body of Scoop

(c) Measure the diameter of the body piece and scribe a circle of that diameter on the piece for the back, allowing $\frac{3}{32}$ of an inch all round for "turning up."

(d) Cut out the back piece, using the straight snips and form the "turned-up" edge, using the Half-moon and small Round stakes.

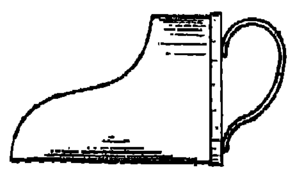
(e) Form $\frac{1}{8}$ inch single fold on each side of the handle strip, using the hatchet stake, and then bend to shape as shown.

Step 4.—ASSEMBLING.



(a) Fit the back piece on to the body of the scoop and solder it carefully around the edge.

(b) Place the handle on to the back of the scoop and solder it carefully in position.



Step 5.—FINISHING OR CLEANING-UP.

(a) Wash off excess flux from the scoop and dry.

(b) Apply a little metal polish to the surface with a piece of waste and rub vigorously until all stains are removed. Polish with a soft cloth.

LIST OF TOOLS USED: Rule, scriber, dividers, try-square, straight and curved snips, flat-faced mallet, piece of pipe, half-moon, round bottom and hatchet stakes and soldering bit.

ART METALWORK.

As the term " Art Metalwork " covers a very wide field, an attempt will be made here to include only a brief survey of the more common processes practised in this art. Art metalwork is usually performed on those metals that are not only attractive in appearance but are also very malleable and ductile and that lend themselves to the processes of hammering and stretching necessary to the changing of their form. The metals and alloys most commonly used for this purpose are copper, brass, pewter and aluminium.

The making of small objects, such as bowls and ash-trays, requires quite an amount of skill and care, mainly owing to the nature of the metals treated.

The following is a brief description, set out in steps, of the operations, and processes to be followed in the forming, or "*raising*," of an ash-tray from copper or brass.

Before, however, commencing operations on the tray, it is necessary to obtain a piece of copper or brass, about 5 inches square, and a doming block to assist in the shaping. A substitute for the latter may be made by obtaining a block of wood and cutting out a hollow, about 3 inches in diameter and ¾ inch deep, in one face.

STEPS IN THE PROCEDURE.

Step 1.—After finding the centre of the piece of metal, scribe a circle, about 3 inches in diameter, on the surface with the dividers.

Step 2.—The metal is now laid on the block, with the scribed circle over the hollowed portion, and the metal within the circle beaten with a bossing mallet until it assumes the shape of the hollow. It will be found that the area outside the circle tends to buckle during this process and should be kept flat by hitting it with the flat-faced mallet whenever necessary.

During the working of the metal it will be found to need annealing frequently as hammering causes it to become hard, brittle and difficult to work. This is done by heating it to a cherry-red colour and quenching in water.

Step 3.—The piece of metal is now removed from the block and placed on a flat surface with the face side down.

The raised portion is beaten in a little way with a bossing mallet, starting from the centre and working in circles

FORMING AN ASH TRAY

towards the edge. It is now turned over and the part just beaten in is flattened out with a flat mallet; this process of hollowing the back and turning the work to flatten out the hollowed part is repeated until the bottom of the original raised portion becomes more or less flat with sides tending towards the vertical.

Step 4.—When the tray has assumed this rough shape it is taken to the round bottom stake, placed over it with the face down and the bottom beaten carefully with a mallet until it is perfectly flat and smooth. The sides are also straightened and sharpened by beating them against the side of the stake with a small hammer.

Step 5.—The edges are sharpened if necessary, by revolving them against the sharp edge of a stake and hitting with a small hammer, care being taken to see that the blows are very light, otherwise the sharp edge of the tool is liable to penetrate the now very thin metal.

This completes the "raising" of the tray. The top surface may now be shaped to some conventional design, such as a circular, hexagonal, octagonal or scalloped form, or to a more intricate shape involving straight and curved lines, used separately or in combination.

The next step towards the completion of the tray is to improve its appearance and enhance its value by working a design upon the surface. The process of doing this is known as repoussé work.

Repoussé Work—is the term used to denote the forming of designs on sheet metal with punches and hammers. The procedure is as follows :—The piece of metal, on which the design is to be worked, must be secured face down to the surface of a block of wood, or pitch, the latter being made by melting pitch in a vessel and pouring it into a shallow wooden mould.

The design to be worked is then drawn directly on to the metal, or may first be drawn on paper and transferred to the metal by means of carbon paper. It is then outlined with a small punch called a "tracer," which is somewhat similar to a chisel in form, except that the edge is blunt and slightly rounded. Tracers are made in different widths and thicknesses, and when in use are held between the thumb and first finger, with a second finger resting on the work to steady the tool and guide it along the line.

Although very many designs can be obtained by using straight and curved tracers, either singly or in combination, the use of punches, with designs such as diamonds, squares and triangles give very pleasing effects. These may be used separately or in conjunction with each other, or with the tracers.

Repoussé Punches—are made of cast steel hardened and tempered to a dark straw colour, and, when in use, should be struck lightly and quickly with a small hammer, otherwise they are likely to be forced through the metal. The hammer generally used for this work is called a repoussé hammer.

Repoussé Hammer—has a wide face and a small ball pane. Its handle is slender and springy, with an oval-shaped knob at the end which allows it to be held comfortably in the hand. (See page 70.)

Finishing—after a suitable design has been worked on the ash-tray, the metal should be cleaned by dipping it in a "pickling" solution, scouring with sand and then polishing, or colouring, it as desired by using some suitable medium.

The general appearance of small models of this type can be improved by mounting them on a neat base made from a piece of nicely-figured timber, such as Silky Oak or Maple. This is done by cutting a small hollow into the surface of the wooden base to accommodate the raised portion of the tray, after which the base is shaped to match and then polished. The tray is finally placed in position on the base and secured to it by means of suitably-coloured screws.

PHOTO OF MODELS.

METAL WORK

Questions :

1. Name the metals commonly used for Art Metalwork.
2. What properties are essential in metals to be used for this purpose ?
3. What is meant by the "raising" of an ash tray or bowl ?
4. What is meant by Repoussé work ?
5. Describe briefly how you would set out your design.

FINISHING AND POLISHING.

In the production of good metal work, not only the cleaning, but also the finish, or polish, given to an article, is very important. Particularly is this so when the appearance, as well as the utility, of an object is to be taken into consideration. These processes embrace not only the removal of marks and stains, or the imparting of a smooth surface to a piece of work, but also any treatment that tends to enhance the appearance of the finished product.

There are very many methods of finishing and polishing various metals, some of which are as follows :—

Tinplate.—Articles made from tinplate are usually polished if necessary with a suitable liquid metal polish. It should be remembered, when using polishes of this nature, that it is not the quantity used that imparts the finish, but rather the method of application. Only a very little polish need be placed on the cloth, but this must be rubbed very hard into the surface until the stains or marks are removed, after which the surface may be polished by rubbing it briskly with a smooth cloth. In other words, surfaces of this nature are best polished by using very little polish and plenty of "elbow grease."

Tinplate can also be given a crystalline finish by heating until the tin is on the point of melting and then dipping it quickly into a solution consisting of 5 ozs. sulphuric acid, ½ oz. nitric acid and 3 pints of water.

Tinplate should never be rubbed with emery cloth as this removes the tin coating from the surface and allows the metal underneath to rust.

Brass and Copper—as well as the other metals used for art metal work—can be finished in a variety of ways. It is necessary to clean these metals before polishing as the heating and working of them causes discoloration. Copper and brass can be cleaned satisfactorily by "pickling," i.e.,

dipping them in a solution consisting of 2 parts sulphuric acid, 2 parts of water and 1 part nitric acid, and then scouring with fine sand. After this treatment the metal should be washed in clean water and allowed to dry. It may then be polished in the ordinary way with metal polish, or by applying a wax polish, as used for furniture, to the surface and rubbing until the metal is bright. If, however, the surface has been badly marked while being worked, it may be necessary to remove these marks with fine emery cloth before polishing.

Buffing Machines are very useful for removing marks from the surfaces of metal articles and for imparting the final polish by using Tripoli Lustre compound, or special polish, on the buffing wheel.

Some very pleasing coloured effects may be given to copper and brass by dipping them into various chemical solutions, e.g., a solution consisting of 2 ozs. sodium thiosulphate (hypo), 2 ozs. lead acetate and 1 pint of water, used hot, will change a brass surface to a steel-blue colour. Copper can also be turned to a rich green colour by placing it in an air-tight box, together with a saucer of water and another of hydrochloric acid, in which has been placed a few pieces of limestone (marble) to make it generate carbonic acid gas, which acts on the copper.

To preserve these colours on the metals they should either be polished with a wax polish or warmed slightly and then lacquered thinly with a soft brush.

Iron and Steel.—Articles and models made from these metals are usually finished in one of three ways :—

1. They are painted with black japan or some suitab[le] lacquer or enamel.

2. Where a bright polished finish is required on [the] metal itself, emery cloth and oil are the mediums use[d]. After the metal has been given a smooth-grained surface, either by draw-filing or in the lathe, it is worked up with emery cloth, commencing with the coarser grades and working through to the finer. It is then polished by placing a few drops of oil on the surface and working it into the

pores of the metal with a piece of worn, fine emery cloth, wrapped around a smooth file or a small piece of wood, used in a manner similar to that used for draw-filing. If the surface is at all dull after this treatment, the lustre may be restored by rubbing with a piece of dry, worn emery cloth, of a fine grade, and then smearing it with petroleum jelly to preserve the polish.

3. Iron and steel may also be coloured by chemical solutions in a manner similar to brass. In preparation for this colouring, the metal must be given a smooth finish, as described above, by draw-filing and using dry emery cloth, but must be free from oil or grease. The solution generally used for the colouring process is a mixture containing 10 grains each of sodium thiosulphate and lead acetate to 1 ounce of water. This is used at a temperature of about 200° F., and depending on the time it is left in the solution, the metal is coloured from light brown, through purples and blues, to black.

Questions:

1. What is meant by the finishing and polishing of metals?
2. Describe one method of finishing tinplate articles.
3. How is brass cleaned prior to polishing?
4. Describe one process of finishing or polishing brass and copper.
5. Describe two methods of finishing iron and steel objects.

DEVELOPMENTS.

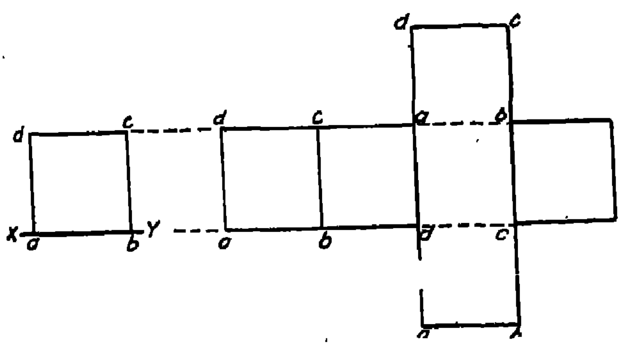
The development, or lay-out, of an object such as a cube or a cone means the drawing of the true shape of its complete surface upon one plane. Development plays an important part in Engineering generally and Sheet Metal work in particular. Many of the objects made have first to be developed on to a plane surface before they can be formed into their correct shapes.

The development of some of the more common geometrical shapes such as :—

1. The Cube	5. The Cone
2. „ Square Prism	6. „ Truncated Cone
3. „ Hexagonal Prism	7. „ Square Pyramid
4. „ Cylinder (and scoop)	8. „ Truncated Pyramid

is set out as follows :—

1. The Cube.

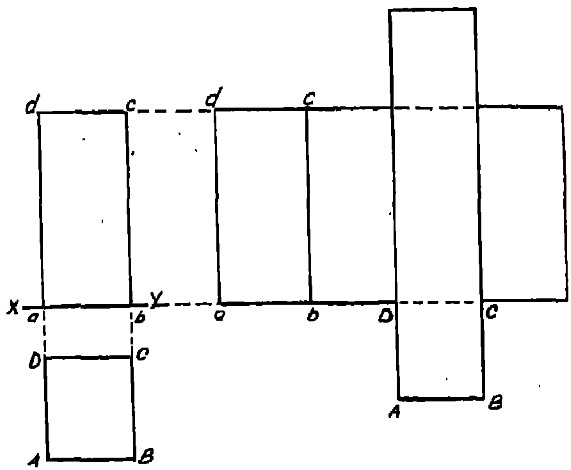


(a) Draw an elevation of the cube as shown.

(b) *Development* : Set out four squares adjoining with sides equal to *ab* to form the sides of the cube.

(c) On each of the opposite sides of any one of the four adjoining squares construct a similar square to form the top and bottom of the cube.

Note: The squares forming the top and bottom of the cube need not necessarily be directly opposite each other.



2. The Square Prism.

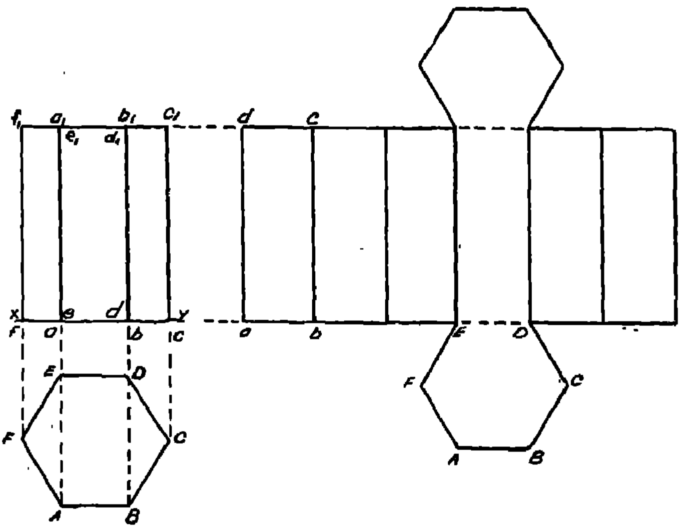
(a) Draw the plan and elevation of the prism, as shown.

(b) *Development*: Set out four rectangles adjoining, with breadths equal to *ab* and lengths equal to the height *bc* to form the sides of the prism.

(c) At each end of any one of the four rectangles *abcd* construct a square equal to the plan ABCD to form the top and bottom of the prism.

Note: As with the cube, the squares forming the top and bottom may be made to coincide with any side equal to *ab* or *cd*.

3. **The Hexagonal Prism.**



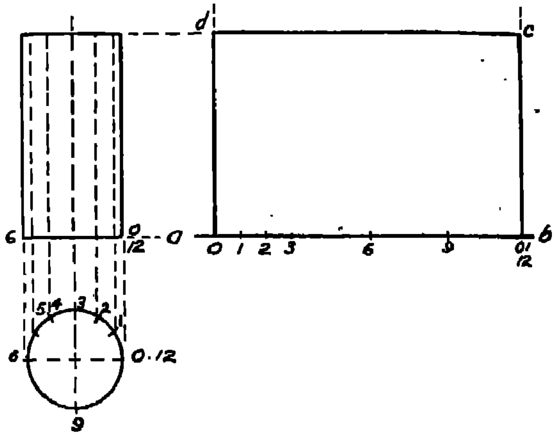
(a) Draw the plan and elevation of the prism as shown.

(b) *Development*: Set out six rectangles adjoining, with breadths equal to *ab* and lengths equal to the height cc_1 to form the sides of the prism.

(c) At each end of any one of the six rectangles abb_1a_1, construct a hexagon equal to the hexagon ABCDEF (the plan) to form the top and bottom of the prism.

Note: The hexagons, one on each side, forming the top and bottoms (or ends) of the prism may be constructed so as to coincide with any of the widths *ab* or a_1b_1.

4. **The Cylinder.**



(a) Draw the plan and elevation of the cylinder, as shown.

(b) Divide one-half of the plan into any number of equal parts, say six, viz., 0, 1, 2, 3-6 and project a line from each of these points up to, and through, the elevation.

(c) *Development* : Draw a line *ab* of any length projected from the base end of the cylinder.

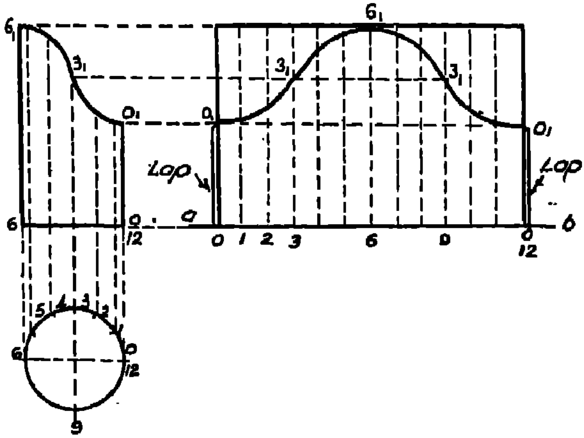
(d) Open the compasses to the length of the chord 0 1 on the plan and step out, along the line *ab* commencing at 0, twelve divisions equal in lengths to 0 1. Then the length of the line 0, 6, 0_1 is equal to the circumference of the cylinder.

(e) From each of the points 0 0_1 raise a perpendicular to the line *ab*.

(f) Open the compasses to a distance equal to the height of the cylinder and step off along each of these perpendiculars to give the points *d* and *c*.

(g) Join *dc*. Then the rectangle o, o_1, c, d is the development of the curved surface of the cylinder.

4a. The Scoop—is developed in a manner similar to a cylinder which is cut by a plane inclined at an angle to its axis.



(a) Draw the plan and elevation of the Scoop, as shown.

(b) Divide one-half of the plan into six equal parts, viz., 0, 1, 2, 3-6 and project a line from each of these points up to, and through, the elevation of the scoop.

(c) *Development*: Draw a line *ab* of any length projected from the base end of the scoop.

(d) Open the compasses to the length of the chord 0·1, on the plan, and step out, along the line *ab* commencing at 0, twelve divisions equal in length to 0 1. Then the length of the line 0, 6, 0 is equal to the circumference of the scoop.

(e) From each of the points along the line *ab* raise perpendiculars.

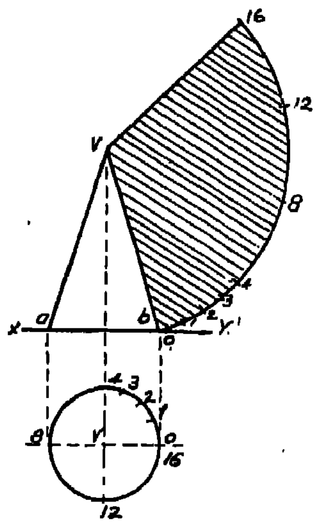
(f) Open the compasses to the length of each of the generators on the elevation, in turn, and step off that distance along the two corresponding perpendiculars raised from the line *ab*.

An alternative method is to project lines from the elevation cutting the corresponding perpendiculars, as shown, at the points $3_1 3_1$.

(g) Join the points marked, on the perpendiculars, with a free-flowing curve to complete the development of the curved surface of the scoop.

Note: Allow lap at each end.

5. The Cone.



(a) Draw the plan and elevation of the cone, as shown.

(b) Divide one-quarter of the plan into any number of equal parts, say four, viz., 0, 1, 2, 3, 4.

(c) *Development*: With the vertex V on the elevation as centre and the radius V*b* (equal to the slant height) draw an arc.

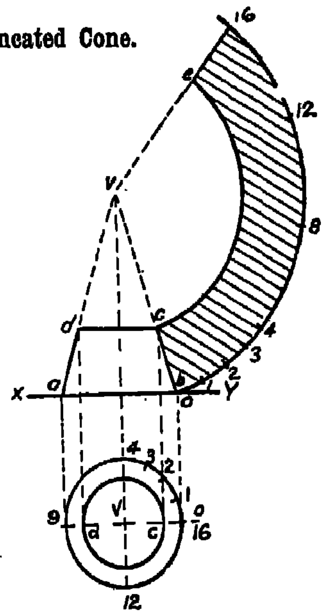
(d) Open the compasses to the length of the chord 0 1 on the plan and step out along the arc, four divisions equal to 0 1.

(e) Open the compasses to the length 0 4 on the arc (equal to four divisions 0 1) and step out along the arc

to give the points 8, 12, 16. Then the length of the arc 0, 16 is equal to the circumference of the base of the cone.

(f) Join the point 16 to the vertex V. Then the figure V, 0, 16, V is the true development of the curved surface of the cone.

6. The Truncated Cone.



(a) Draw the plan and elevation of the truncated cone and extend the slanting sides on the elevation until they meet at the vertex V, as shown.

(b) Divide one-quarter of the plan into four equal parts, viz., 0, 1, 2, 3, 4.

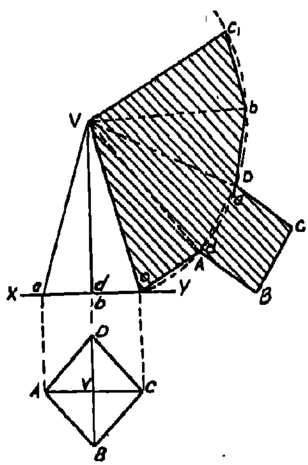
(c) *Development*: With the vertex V on the elevation as centre and the radius Vb, draw an arc similar to that drawn for the cone.

(d) Step out along the arc four divisions equal to 0 1 giving 0, 1, 2, 3, 4.

(e) Open the compasses to 0 4 on the arc and step out three further divisions to give the points 8, 12, 16. Join the point 16 to the vertex.

(f) With V as centre and radius V*c* (equal in length to V*b* less *cb*, the slant height of the truncated cone) draw a second arc commencing at *c* on the elevation and terminating at *e* on the line V 16. Then the figures *c*, 0, 16, *e*, *c* is the true shape of the surface of the Truncated Cone.

7. The Square Pyramid.



(a) Draw the plan and elevation of the Square Pyramid with its base edges, making equal angles with the vertical plane (V.P.) as shown.

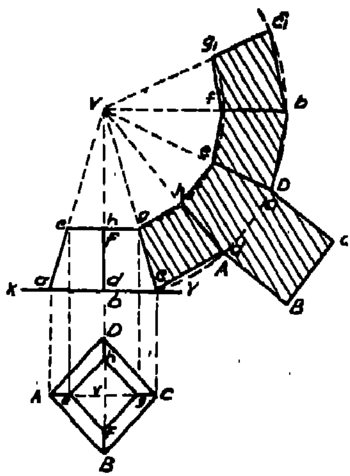
(b) *Development*: With the vertex V, on the elevation as centre and the radius V*c* (equal to the slant edge of the pyramid) draw an arc commencing at *c*.

(c) Along the arc, commencing at *c*, set off the four sides *cd*, *da*, *ab* and bc_1 each equal to the base side AB.

(d) Join the points *d*, *a*, *b* and c_1 to the vertex V. Then the four triangles converging at the vertex V form the sides of the square pyramid.

(e) On any one of the sides marked off along the arc, construct a square equal to the plan ABCD to form the base and complete the development of the Square Pyramid.

8. The Truncated Square Pyramid.



(a) Draw the plan and elevation of the truncated pyramid and extend the slanting sides on the elevation until they meet at the vertex V, as shown.

(b) *Development*: With the vertex V, on the elevation, as centre and the radius Vc draw an arc commencing at c similar to that drawn for the Square Pyramid.

(c) Along the arc commencing at c set off four divisions equal to the base side AB to give the points d, a, b and c_1. Join these points to the vertex V.

(d) With the centre V and the radius Vg (equal in length to Vc less gc the length of a slant edge of the truncated pyramid) draw a second arc commencing at g and terminating at g_1 on the line Vc_1.

(e) Join the points g, h, e, f and g_1 where the second arc gg_1 cuts the lines dV, aV, and bV at the points h, e and f respectively. Then the figure bounded by the points g, c, c_1, g_1, g is the development of the sides of the truncated pyramid.

(f) On any one of the sides cd, da, ab or bc_1 on the arc cc_1 construct a square equal to the plan ABCD to form the base of the truncated pyramid and complete the development.

Note: In step "e" instead of drawing the second arc gg_1, the distances dh, ae, bf and c_1g_1 may be obtained by opening the compasses to the length cg (the slant edge) on the elevation, and setting off the distance along each of the lines dV, aV, bV and c_1V to give the points h, e, f and g_1 respectively.

SOME PRACTICAL PROBLEMS FOR STUDENTS.

The following series of progressive "snap" tests or "*quizzes*," are designed to cover the range of work set out in this book. It is suggested that they be given at suitably spaced intervals throughout the course.

TEST—A.

1. Name the common types of Tinman's Snips.
2. State the uses of the various types.
3. Name the parts of the Snips.
4. Name the materials used for the various parts.
5. Sketch and describe what is meant by the "shearing" action of the snips.
6. Name the parts of a Soldering Bit.
7. Name two common types of Bits.
8. Why is copper preferable to other metals for making the head of the Soldering Bit ?
9. Why are only thin metals joined with a Soldering Bit ?
10. What precautions are necessary when heating a bit ?

TEST—B.

1. Why is it necessary to tin a Copper Bit ?
2. Set out the procedure when tinning a bit.
3. Give a reason for using each step in the procedure.
4. What are the effects of overheating on a Copper Bit ?
5. State the chief reasons for using a flux when Soldering.
6. What is meant by cleansing and protective fluxes ?
7. Name two fluxes with a cleansing action and two with a protective action.

8. State a flux you can use when soldering Tinplate. Zinc, Brass, Pewter.
9. State the use of the Soldering Bit.
10. State the use of the Straight and Curved Snips.

TEST—C.

1. What is Soft Soldering ?
2. Discuss three of the points that help in the production of good Soldering.
3. What are the properties of a good solder ?
4. Why must the melting point of solder be lower than that of the metals to be soldered ?
5. What is meant by Brazing ?
6. What is Spelter ?
7. What is the value of borax as a flux when Brazing ?
8. What is meant by Silver Soldering ?
9. Why is it necessary to "tin" a new Soldering Bit ?
10. How would you prepare "Killed Spirits" ?

TEST—D.

1. What is meant by "Covered" sheet metals ?
2. What is meant by "Alloyed" sheet metals ?
3. Name two Covered and two Alloyed sheet metals.
4. Name two types of Mallets and state their uses.
5. Name the parts of a Mallet and the materials that may be used for making these parts.
6. Why are Mallets preferable to Hammers for use on thin sheet metals ?
7. How does Brazing differ from Soft Soldering ?
8. What metals are used in the composition of Spelter ?
9. State a flux you could use when soldering Galvanized Iron and Copper.
10. Set out the steps to be followed when "tinning" a copper bit.

TEST—E.

1. Name four common Stakes and state their uses.
2. Name the parts of a Stake.
3. From what metals are Stakes usually made ?
4. Why should mallets, and not hammers, be used when shaping metal on the Stakes ?
5. What use is made by the metalworker of Seams and Joints ?
6. Sketch, and state the uses of three " Angle " Seams.
7. Sketch, and state the uses of three " Flat " Seams.
8. Describe two methods of finishing edges in sheet metal work.
9. Name three " pure " metals commonly used in sheet form.
10. Sketch, and describe the " Shearing " action of the Snips.

TEST—F (*Revisionary*).

1. Name and state the uses of both types of Snips.
2. Why is copper preferred to other metals for the head of the Soldering Bit ?
3. Set out the steps in the procedure of "tinning" a Copper Bit—give reasons.
4. State the four main reasons for using a flux when soldering.
5. What is meant by Soft Soldering and Hard Soldering ?
6. Name and state the composition of the fusible alloys used when Soldering and Brazing.
7. Name two of the metals in each of the Covered, Pure and Alloyed sheet metal groups.
8. Name two types of Mallets and the materials from which these are made.
9. State the uses of the Bick Iron, the Creasing and the Hatchet Stakes.
10. Sketch, name, and state the uses of two Flat seams and two Angle seams.

TEST—G.

1. Name the two main types of Engineer's Vices.
2. What is the average height of a Vice from the floor?
3. Describe and state the use of Vice Clamps.
4. What is the function of a Filing Board?
5. Name three types of Pliers.
6. State three uses of the Pliers.
7. What is meant by "parallel-grip" action in the jaws of certain types of pliers?
8. Describe three methods of finishing edges in sheet metal work.
9. Why is a mallet, and not a hammer, used in conjunction with the Stakes?
10. What is the angle of the cutting edges of the Snips?

TEST—H.

1. Name the three most common types of Engineer's Hand Hammers.
2. Name the parts of a Hammer and state the material of which these parts are made.
3. State two of the points to be observed when using a Hammer.
4. How are Hammers graded or specified?
5. Name four types of Chisels in common use.
6. State the uses of two types of Chisels.
7. What is the angle of the cutting edge of a chisel for general use?
8. When may this cutting angle be reduced?
9. Why is the inside of the jaws of the Vice or Pliers serrated or roughened?
10. What is meant by an "Instantaneous Grip" Vice?

TEST—J.

1. What is meant by the "length" of a File?
2. Sketch three shapes of Files and state the use of each.
3. Name the two "cuts" of Files usually used by engineers.

4. Why does the grade of a file depend on the cut? Name three grades.
5. When is the process of Scraping employed?
6. Name the three most common types of Scrapers.
7. Which Scraper is used for working on flat surfaces?
8. How would you sharpen the cutting edge of a flat Scraper?
9. Why does the eye of the hammer head taper from both ends towards the centre?
10. What is the disadvantage of the Leg type of Vice?

TEST—K.

1. What are Hacksaws?
2. Compare the fixed and adjustable types of Hacksaw.
3. Name the parts of a Hacksaw.
4. How would thin metals be cut with a Hacksaw?
5. What is meant by the term "Marking-off"?
6. Name five Marking-off, Measuring and Testing tools.
7. Name two of the mediums that may be used for coating surfaces preparatory to Marking-off.
8. What is "Reddle"? How would you prepare it?
9. Name the parts of a File.
10. What is the advantage of a "safe-edge" File?

TEST—L.

1. Name four different types of Squares.
2. Name the parts of a Try-square.
3. How are Try-squares specified?
4. State the uses of the Try-square.
5. Name the two types of Dividers.
6. Which type of Divider is preferable for finer and more accurate work? And why?
7. State the uses of the Dividers.
8. How would you set the Dividers from a rule?

9. What is the advantage of the soft-back type of hacksaw blade ?
10. Why is the cutting edge of the flat scraper ground slightly convex ?

TEST—M (*Revisionary*).

1. Name the main types of Vices.
2. Name two types of Pliers and state their uses.
3. Name the parts of the Hammer head.
4. Give the grinding angle of Chisels for cutting cast steel and brass.
5. What three characteristics distinguish a File ?
6. What is meant by Scraping ?
7. What advantage has the adjustable Hacksaw over the fixed type ?
8. What is meant by "Marking-off" ?
9. Describe briefly the "built-up" type of Try-square.
10. Compare the Spring Dividers with the Wing Compasses.

TEST—N.

1. State the uses of the Outside and Inside Calipers.
2. How would you set the Inside Calipers from the Rule ?
3. Why should Calipers be lightly grasped when using ?
4. What is the advantage of the Lock-Joint Calipers ?
5. How does the knowledge of the Properties of metals assist an engineer ?
6. What advantage is taken of the Ductility of metals ?
7. Compare Toughness and Brittleness.
8. Which metal is the best conductor of heat and electricity ?
9. What is the function of the Scribing Block ?
10. State the use of the Surface Plate.

TEST—O.

1. Name four Ferrous Metals and the Furnaces used for their manufacture.
2. Give the approximate carbon content of each of the Ferrous metals.
3. What is the effect of a reduction or addition of carbon to Ferrous metals ?
4. What are Alloy steels ?
5. In which way do Non-Ferrous differ from Ferrous metals ?
6. Name three Non-ferrous metals.
7. State their characteristics and uses.
8. Which of the Non-Ferrous metals is liquid under ordinary atmospheric conditions ?
9. State the uses of the Jenny, or Odd-leg, calipers.
10. What is the use of a Depth Gauge ?

TEST—P.

1. What is an Alloy ?
2. What advantages are gained by alloying metals ?
3. Name three of the alloyed metal groups.
4. Name one metal in each group.
5. What is meant by Annealing ?
6. How would you anneal Steel and Brass ?
7. Why are tools tempered ?
8. What advantages are gained by Case-hardening metals ?
9. What is the use of the Centre-Square ?
10. What is a File Brush ?

TEST—Q.

1. What is meant by the term "alloy steels" ?
2. Name four elements used in the making of alloy steels,
3. Name the groups into which stainless steels may be divided.

4. Name three of the chief uses of stainless steel.
5. What are the constituents of monel metal ?
6. What do you understand by the term "plasticity" ?
7. Name the two classes into which welds may be divided.
8. Name two different methods of welding.
9. State the usual composition of silver solder.
10. What are the chief uses of Terne plate ?

TEST—R.

1. What is Tinplate, and Galvanized Iron ?
2. What is the chief use of Tinplate ? And why ?
3. Why is Galvanized Iron corrugated ?
4. What is meant by "pickling" the black-iron sheets ?
5. What is meant by "Drilling" ?
6. Name four Drills and state their uses.
7. Name two types of Drilling machine.
8. What is meant by "Drawing-over" a hole ?
9. What do you understand by the Malleability of a metal ?
10. To which alloy group does Solder belong ?

TEST—S.

1. Name the parts of the Machine Bolt.
2. What is the advantage of a Stud over a Cap Screw ?
3. What are "safety" Set-screws ?
4. Describe two Nut-Locking devices.
5. What are the necessary requirements in a Screw Thread ?
6. Sketch and give details of the Whitworth and Square threads.
7. What is the included angle of the Sellers, and the Acme Thread ?
8. Write down the full name and the included angle of the B.A. Thread.
9. What is meant by Cross-filing ?
10. What do you understand by Draw-filing ?

TEST—T. (*Revisionary*).

1. Name the three types of Firm-joint calipers.
2. Name four Properties of metals.
3. Name the Furnaces used for making Mild Steel.
4. How do Non-Ferrous metals differ from alloys ?
5. Name three of the alloyed metal groups.
6. Compare the Annealing and Hardening of metals.
7. How are black iron sheets cleaned prior to being coated with tin or zinc in the manufacture of Tinplate and Galvanized Iron ?
8. What is meant by " Drilling " ? Name three common types of drills.
9. What functions do Bolts, Nuts and Screws perform in the engineering workshop ?
10. What are the two groups into which Screw Threads may be divided ?

TEST—U.

1. What function is performed by Taps ?
2. Name the three Taps that comprise a set.
3. State what is meant by the tapping size of a hole.
4. Write down a formula for calculating the tapping size of a hole.
5. What is the function of Stocks and Dies ?
6. What is meant by " humouring " the die ?
7. How is the blank rod treated before commencing to cut a thread ?
8. What is a Screw plate ?
9. Describe a Carriage bolt.
10. How would you anneal Zinc or Aluminium ?

TEST—V.

1. Name two Spanners and state their uses.
2. Why are the ends of mild steel Spanners case-hardened ?
3. To what does the fraction, stamped on the ends of certain Spanners, refer ?
4. How would you calculate the width across the jaws of a Spanner ?

5. What is the chief function of a Lathe ?
6. Name the main parts of a Lathe.
7. State one method of drilling work in the Lathe.
8. Name two Lathe tools and state their uses.
9. What would be the tapping size of a hole to receive a ½ inch diameter Whitworth bolt ?
10. What is a stud box ?

TEST—W.

1. Name two cooling agents used when hardening metals.
2. What is meant by the term "Nitriding" ?
3. State the chief advantages of Induction heating.
4. What is Zinc anneal ?
5. State a definition for "tolerance" and "allowance."
6. Name two types of shaping machines.
7. Describe two types of drive used in shapers.
8. Name three shaper tool groups.
9. State the definition of a belt.
10. Name the two main types of pulleys.

TEST—X.

1. What is meant by Forging ?
2. What is a reducing fire ?
3. Give the names of the chief Heats used in forge work.
4. Name three Primary forging operations.
5. Why are Grinding Wheels preferred to Grindstones ?
6. What causes grooving and bevelling on the face of a Grinding Wheel ?
7. What are Oilstones ?
8. How would you "true" an Oilstone ?
9. What three metals are most commonly used for making castings ?
10. State the two divisions of moulding.

TEST—Y.

1. Set out the five steps to be followed in the construction of a model.
2. Name two of the metals commonly used in Art Metal work.
3. Why must the metals used for this purpose be malleable ?
4. What is Repoussé work ?
5. What is meant by the Finishing and Polishing of metals ?
6. How is brass cleaned prior to polishing ?
7. Describe one method of finishing tinplate models.
8. After colouring a brass object, how would you preserve the surface ?
9. What do you understand by the development of an object ?
10. Make a sketch of the development of a Square Prism.

TEST—Z. (*Revisionary*).

1. When Tapping how do you ensure that the tap will enter the hole squarely ?
2. When cutting external threads, why is it an advantage to have adjustable dies ?
3. Why are the jaws of Machine Spanners usually offset 15° to the axis of the handle ?
4. What is meant by Parallel and Stepped turning in lathe work ?
5. Sketch and name four classes of Welds used in Forge work.
6. What is the name of the tool used for truing emery wheels ?
7. In the construction of a model, what do you understand by "Operations" ?
8. From what metal are Repoussé Punches made ?
9. In the finishing of a copper object, explain the process of colouring it a rich green.
10. Make a free-hand sketch of the development of a Truncated Cone.

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

METAL WORK — THEORY EXAMINATION.

No. 1.

1. (a) What is an alloy ?

   (b) Describe the alloys with which you are familiar, stating the metals of which they are composed, their properties, and the uses to which they are put.

2. You are required to make a tube of galvanized-iron which is to have a ½ inch lapped joint and to be 12 inches long by 3 inches diameter. What would be the size of metal that you would use for this purpose ?

3. (a) Give the melting points of zinc and copper. Is there any difference in the manner in which you would solder each of these metals ?

   (b) How would you distinguish tinplate from zinc, and solder from lead ?

4. State the composition of sheet brass. What fluxes may be employed in soldering brass ? What operations are necessary to make a good job of soldering old brass ?

5. Describe and give the uses of the following tools and implements :—

Hatchet Stake, Compasses or Dividers, Mandrel.

6. In each of the following pairs of metals or alloys state which is the heavier :—

(a) Lead and platinum ;
(b) copper and silver ;
(c) zinc and galvanised iron ;
(d) aluminium and tin-plate ;
(e) brass and gold.

7. Trace the processes which are followed in making black sheet-iron from cast-iron.

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

METAL WORK — THEORY EXAMINATION.

No. 2.

1. As files of the same grade differ in length, so does the distance between the teeth of the file differ; for instance, a file 6 inches in length would not have the teeth cut as coarse as a file 12 inches long. What is the usual number of teeth per inch for the files mentioned, assuming they are bastard type?

2. In order to allow the whole surface of the file to be used on any broad surface, sketch and briefly describe a file handle suitable for this purpose.

3. Make a sketch of a cheese-headed bolt, and briefly describe how the bolt may be prevented from turning when the nut is being screwed up, and what means are adopted to prevent the nut unscrewing (or working loose), which it may do owing to the vibration of the machine when in motion.

4. Scraping is adopted for the purpose of making a perfect contact between metal surfaces.
   (a) Briefly describe the type of job a flat scraper would be used on.
   (b) On what type of job would it be necessary to use a triangular scraper?
   (c) Briefly describe and give an example of any process you are aware of for producing the same result as scraping.

5. Make sketches showing three forms of spanners used for tightening up bolts and nuts.
   (a) Give the most suitable angle for the spanner jaws.
   (b) What should be the length of a spanner handle?

6. Show by sketches three forms of bolts usually employed for securing engine beds, etc., to stone foundations. What means would you adopt to prevent the nut working loose?

7. How is brazing done? Give example of brazed work.

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

METAL WORK — THEORY EXAMINATION.

No. 3.

1. Make sketches of a ball pane and cross pane hand hammer heads. From what material are they made? State whether they are hardened; if so, what part, and why?

2. Describe with the aid of sketches four different types of engineers' chisels, stating some operation for which each one is designed to perform. Does the cutting angle vary for cutting hard and soft materials; if so, why?

3. How many different types of bolts and nuts are you acquainted with? Make sketches to show the shapes of them, and briefly describe their uses.

4. You are given half a dozen bolts which are to have a thread cut on them. Describe the operation necessary to do the job, and also make a sketch to illustrate the tool used for producing the screw threads.

5. Write a brief but concise account of the characteristics of brass, gunmetal, and white metal.

6. How many comprise a set of engineers' Whitworth standard screw taps? What is the difference in their shape?
What would be the diameter of a drill for boring holes to be tapped for ½ inch diameter studs? Show your method of obtaining the tapping size.

7. (a) Sketch and describe three types of drills.
   (b) Enumerate the points to be observed in drilling.
   (c) How would you correct a drill that has run out of position?

METAL WORK

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

METAL WORK — THEORY EXAMINATION.

No. 4.

1. (a) Describe three different kinds of drills and discuss their advantages and disadvantages.
   (b) State how you would mark out and drill a half-inch hole in a piece of mild steel plate.

2. Select any model made by you during your course and describe the method of making it. The different steps in its construction must be clearly set out.

3. State what you can about the manufacture, properties and uses of cast-iron.

4. (a) Why are fluxes used in soldering?
   (b) Name the fluxes used in soft soldering and the metals for which they are suitable.
   (c) Describe the process of brazing.

5. (a) Give sketches of five different shapes of files and state the uses of each.
   (b) Explain the meaning of the word "cut" as applied to files.
   (c) Describe the method of holding a file and the position of the user.
   (d) What is the proper height for a parallel vice in which filing is done?

6. Describe and state the uses of:—Wing nut, set screw, stocks and dies, 3 types of taps, 3 types of spanners.

7. Describe briefly the following operations in lathe work:—Turning to a shoulder, surfacing, turning taper, cutting off or parting.

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

METAL WORK — THEORY EXAMINATION.

No. 5.

1. Give the characteristics and uses of :—
   (a) Mild steel, tool steel.
   (b) Three alloys in common use.

2. (a) Name three Whitworth taps comprising a set, and state how they are used.
   (b) What would be the tapping size of a hole to be screwed to receive a half-inch Whitworth bolt? Give your method of obtaining the tapping size.

3. (a) Describe the following operations: Cross filing, draw filing, drilling and riveting.
   (b) Explain how a drill may be drawn back on centre after it has been moved out of position.

4. (a) Name and describe the uses of four different stakes used in sheet metal work.
   (b) Sketch a cross section of each of the following: Folded seam, grooved seam, circular over-folded seam.

5. Describe, with the aid of sketches, three types of calipers in common use. State the special uses of each.

6. Name two operations, with which you are familiar, that can be carried out in a lathe. Briefly describe each.

7. You are given a block of cast-iron 4 inches square and two inches thick which is to be reduced to $1\frac{7}{8}$ inches thick by taking $\frac{1}{8}$ inch off one face. The surface is to be made very smooth and flat. Hand tools only are to be used. Describe how you would do the work.

METAL WORK

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

METAL WORK — THEORY EXAMINATION.

No. 6.

1. State the uses of the following tools: Flat file, hand file, outside calipers, centre punch, cross-cut chisel, countersink, bossing mallet, rivet set, groover, hatchet stake.

2. (a) Make a working sketch of one of the jobs made by you during the year.
   (b) Give a list of the tools used.
   (c) Set out the steps to be followed in its construction.

3. (a) From what metals are the following made: Engineer's rule, bolt and nut, water pipe, water tap, cold chisel, file, soldering bit, forge tongs, tinmen's stakes.
   (b) Briefly describe the manufacture of cast-iron.

4. (a) State clearly the difference between hard and soft soldering.
   (b) What is a flux, and why is it used?
   (c) State the fluxes used in soldering tinplate, lead, zinc, copper and galvanized iron.

5. (a) Describe, with the aid of sketches, the construction of an engineer's parallel bench vice.
   (b) What precautions would you take in order to prevent a piece of work becoming damaged by the jaws of the vice?

6. State what is meant by the following: Draw filing, cross filing, riveting, tapping, drilling, boring, sweating, annealing, tempering, case-hardening.

7. (a) State what is meant by the following: Lathe carrier, driving plate, tail stock, parting tool.
   (b) Describe how you would turn a steel spindle 6 inches long, 1 inch diameter at one end, and ¾ inch diameter at the other end.

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

FORGEWORK—THEORY EXAMINATION.

No. 1.

1. Show by sketches what a hand forge is. Explain how it is worked, and how the blast is generated.

2. Give a description how to make an angle bracket. Explain how you would make a ring scroll; assemble same and finish.

3. Give a list of tools necessary for the fire. Name at least four of the hand tools required for a blacksmith to work with at the anvil. Explain their use.

4. Give the names of all the parts of an anvil. Show rough sketch, with parts numbered, and explain their use.

5. (a) Give the use of the following tools: Hot set, hollow bit tongs, flatter, hardie.
   (b) Describe process of lap welding.

6. Explain what you know about annealing iron and steel.

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

FORGEWORK—THEORY EXAMINATION.

No. 2.

1. Give a short description of the manufacture of ferrous metals.

2. Make a sketch, plan and side view of a poker. Give dimensions of every part. Explain how you would make same.

3. Describe one method of making a ring for a tripod stand. Give size of material and dimensions of ring.

4. Give a short definition of the terms annealing, hardening, tempering and case-hardening.

5. What is meant by the term carbon steel? State the range of carbon contents (percentage) in ordinary carbon steel.

6. Explain what is meant by the terms drawing out, bending and welding. Give an example which requires these three movements to complete the job.

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

FORGEWORK — THEORY EXAMINATION.

No. 3.

1. Give the different properties of wrought-iron, mild steel and tool steel or cast-steel. Explain the degrees to which these qualities are possessed by these materials, and which render each better adapted for certain purposes than the other. State the purpose for which each is best suited.

2. Explain how to work a hand forge. State what you think is the best fuel. Show by sketches how the blast is generated and enters the fire. Also state what you think is the best method to adopt for a power generator of blast.

3. Explain how you would forge hand chisels for a fitter. State what you think is the best class of steel to resist a shock or blow. Give the method of tempering chisels.

4. Give a list of six of the most important elementary tools required in forge work. Explain their use and how they are applied.

5. Give an explanation of how to prepare and weld two pieces of half inch round mild steel together. State at what temperature (degrees Fahrenheit) the mild steel should be heated to make a good weld.

6. Give the weights of the following three pieces of mild steel: 1½ inch square, 11 inches long, 1½ inch diameter; round 11 inches long, 3 inches × 1 inch; flat, 12 inches long. Show how to work it.

DEPARTMENT OF EDUCATION.

WORKSHOP PRACTICE.

FORGEWORK — THEORY EXAMINATION.

No. 4.

1. (a) What are the chief heats used in forging?
   (b) State the "temper" colours for cold chisels, centre punches, hammer faces and screwdrivers.

2. Make a sketch of an anvil. Name the different parts and explain their use.

3. Write a brief but concise account of the method of manufacturing iron and steel.

4. Give an explanation how to make a shovel. Show by sketches the different steps.

5. Explain how to make a link for a chain. Show the method to calculate the length of material required, and finally show by sketches how to complete the three-link chain.

6. Give all the dimensions, and show sketches of the method of making a rake; also explain the different steps in making a rake.

METAL WORK—PRACTICAL TEST.

Time allowed—Three hours.

One of the following tests is to be undertaken.

Test No. 1.

Construct the ring spanner shown in Fig. 1.

Material approximately $\frac{1}{8}$ inch thick will be supplied for this job. In filing the flat surfaces only the minimum amount of metal should be taken off.

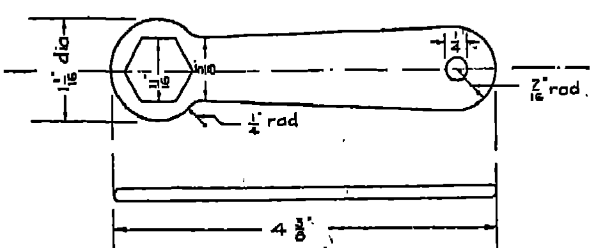


FIG 1

Test No. 2.

Construct the pint measure shown in Fig. 2.

Materials to be used—tinplate and wire.

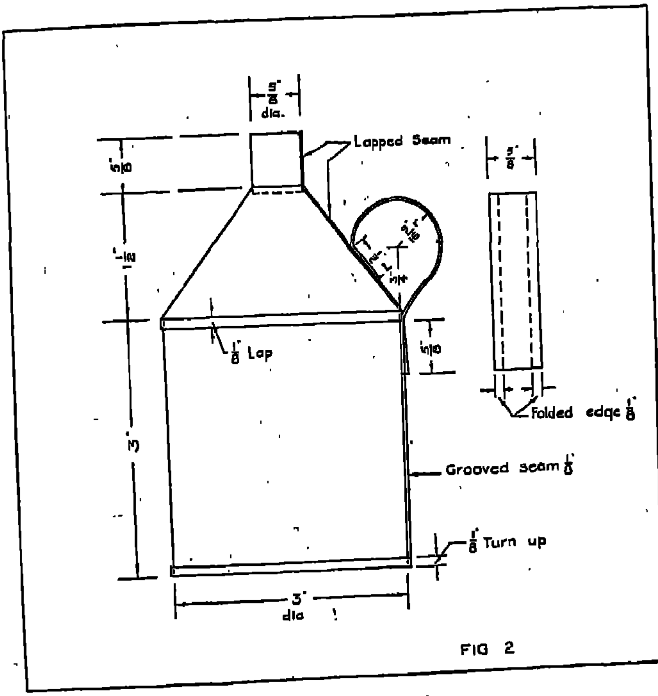


FIG 2

METAL WORK—PRACTICAL TEST.

Time allowed—Three hours.

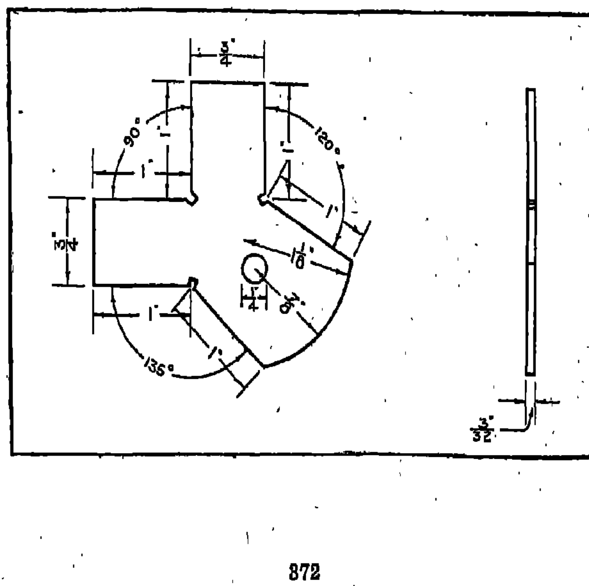
One of the following tests is to be undertaken.

Test No. 1.

Construct the nut gauge shown in the drawing.

Material approximately the thickness shown in the drawing will be supplied. In filing the flat surfaces only the minimum amount of metal should be taken off, about $\frac{1}{64}$th of an inch.

Accuracy of work will be the chief consideration in awarding marks.

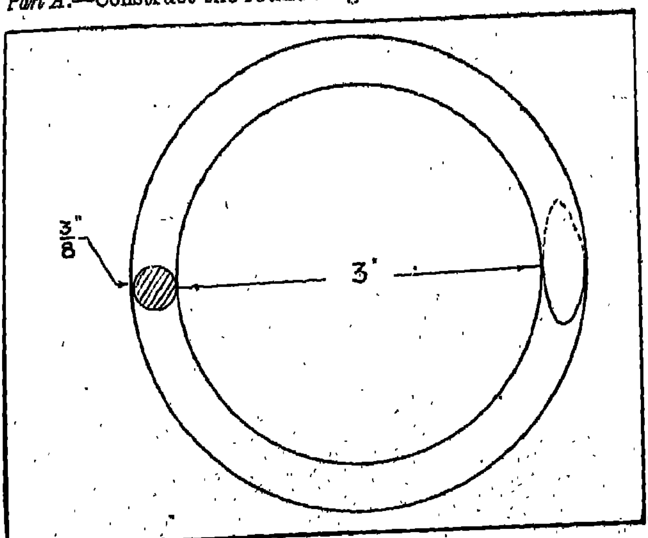


NUT GAUGE.

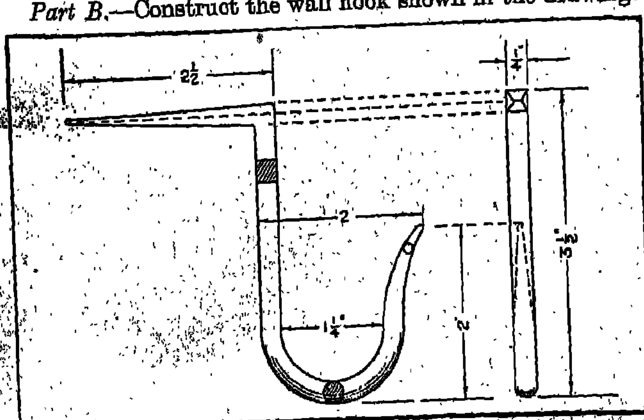
Test No. 2.

Forge Work Exercises.

Part A.—Construct the round ring shown in the drawing.



Part B.—Construct the wall hook shown in the drawing.



METAL WORK — PRACTICAL TEST.

Time allowed—Three hours and a half.

One of the following tests is to be undertaken.

Test No. 1.

Construct the try square shown in Fig. 1. Materials of the following thicknesses will be supplied:—

(a) For the right-angled piece, part of which forms the blade, and the other part the central portion of the built-up stock—mild steel, $\frac{1}{16}$ of an inch thick. This should be cleaned up only lightly with the file.

(b) The side pieces of the stock—mild steel, $\frac{3}{16}$ of an inch thick.

(c) Rivets—mild steel, $\frac{1}{8}$ of an inch in diameter

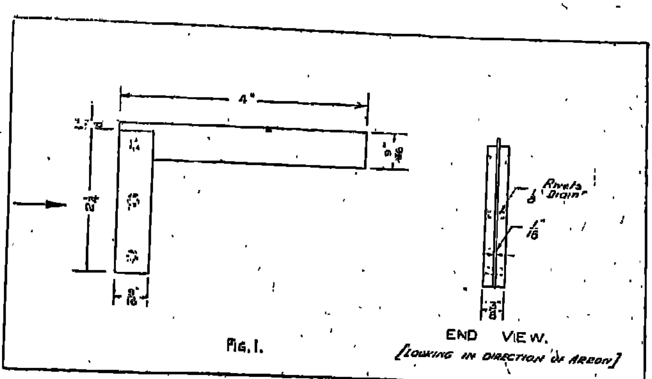


FIG. I.

Test No. 2.

Construct an oil bottle shown in Fig. 2.

Tin plate is to be used in its construction.

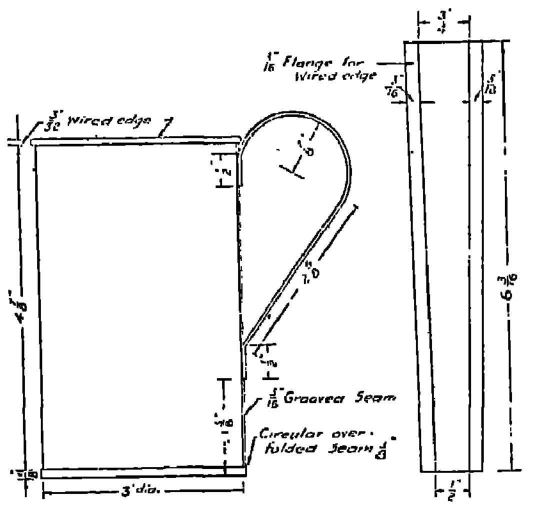
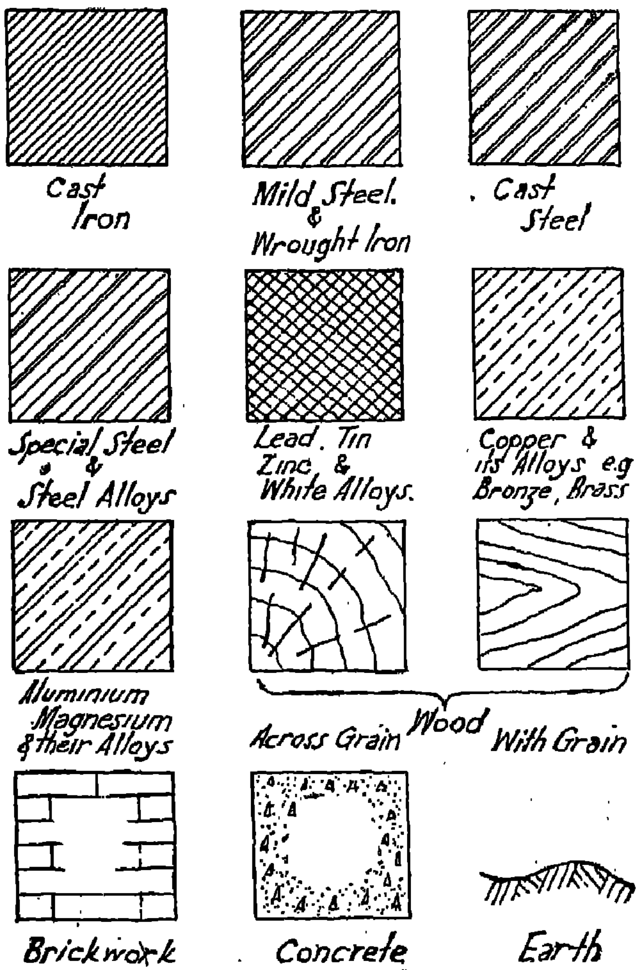


FIG. 2.



STANDARD HACHURES.

TABLE OF DECIMAL EQUIVALENTS.

8ths, 16ths, 32nds and 64ths of an inch.

Fractions				Decimals	Fractions				Decimals
$\frac{1}{64}$				015625	$\frac{33}{64}$				.515625
	$\frac{1}{32}$			03125		$\frac{17}{32}$			.53125
$\frac{3}{64}$				.046875	$\frac{35}{64}$				.546875
		$\frac{1}{16}$		0625			$\frac{9}{16}$		.5625
$\frac{5}{64}$				078125	$\frac{37}{64}$				.578125
	$\frac{3}{32}$			09375		$\frac{19}{32}$			.59375
$\frac{7}{64}$				109375	$\frac{39}{64}$				.609375
			$\frac{1}{8}$	125				$\frac{5}{8}$	.625
$\frac{9}{64}$				140625	$\frac{41}{64}$				.640625
	$\frac{5}{32}$			15625		$\frac{21}{32}$			.65625
$\frac{11}{64}$				171875	$\frac{43}{64}$				.671875
		$\frac{3}{16}$		1875			$\frac{11}{16}$		.6875
$\frac{13}{64}$				203125	$\frac{45}{64}$				.703125
	$\frac{7}{32}$			21875		$\frac{23}{32}$			.71875
$\frac{15}{64}$				.234375	$\frac{47}{64}$				.734375
			$\frac{1}{4}$	.25				$\frac{3}{4}$	.75
$\frac{17}{64}$				265625	$\frac{49}{64}$				.765625
	$\frac{9}{32}$			28125		$\frac{25}{32}$			.78125
$\frac{19}{64}$				.296875	$\frac{51}{64}$				.796875
		$\frac{5}{16}$		3125			$\frac{13}{16}$		.8125
$\frac{21}{64}$				328125	$\frac{53}{64}$				.828125
	$\frac{11}{32}$			34375		$\frac{27}{32}$			.84375
$\frac{23}{64}$				359375	$\frac{55}{64}$				.859375
			$\frac{3}{8}$	.375				$\frac{7}{8}$	.875
$\frac{25}{64}$				390625	$\frac{57}{64}$				.890625
	$\frac{13}{32}$			40625		$\frac{29}{32}$			.90625
$\frac{27}{64}$				421875	$\frac{59}{64}$				.921875
		$\frac{7}{16}$		4375			$\frac{15}{16}$		.9375
$\frac{29}{64}$				453125	$\frac{61}{64}$				.953125
	$\frac{15}{32}$			46875		$\frac{31}{32}$			.96875
$\frac{31}{64}$				484375	$\frac{63}{64}$				.984375
			$\frac{1}{2}$	.5				1	1.00

USEFUL TABLES AND DATA.

Rules Relative to the Circle, etc.

To find the Circumference—

Multiply diameter by 3.1416
Or divide diameter by 0.3183.

To find the Diameter—

Multiply circumference by 0.3183
Or divide circumference by 3.1416.

To find the Radius—

Multiply circumference by 0.15915
Or divide circumference by 6.28318.

To find the Side of an Inscribed Square—

Multiply diameter by 0.7071,
Or multiply circumference by 0.2251,
Or divide circumference by 4.4428.

To find the Side of an Equal Square—

Multiply diameter by 0.8862
Or divide diameter by 1.1284,
Or multiply circumference by 0.2821,
Or divide circumference by 3.545.

Square—

A side multiplied by 1.442 equals the diameter of its circumscribing circle.
A side multiplied by 4.443 equals the circumference of its circumscribing circle.
A side multiplied by 1.128 equals the diameter of an equal circle.
A side multiplied by 3.547 equals the circumference of an equal circle.
Square inches divided by 1.273 equal square inches of inscribed circle.

To find the Area of a Circle—

Multiply circumference by one-quarter of the diameter
Or multiply the square of the diameter by 0.7854,
Or multiply the square of the circumference by .07958,
Or multiply the square of half the diameter by 3.1416.

To find the Surface of a Sphere or Globe—

Multiply the diameter by the circumference
Or multiply the square of diameter by 3.1416,
Or multiply four times the square of radius by 3.1416.

To find the Weight of Brass and Copper Sheets, Rods and Bars—

Ascertain the number of cubic inches in the piece and multiply same by weight per cubic inch.

Brass, 0.2972.

Copper, 0.3212.

Or multiply the length by the breadth (in feet) and the product by the weight in pounds per square foot.

Circumferences, Areas, Squares, etc., of Circles.

Advancing by 16ths, 8ths and 4ths—1 to 50.

Diameter or No.	Circumference	Area	Square	Cube	Square Root	Cube Root
1	3.14	.7854	1	1	1	1
1 1/16	3.34	.886	1.13	1.19	1.031	1.020
1 1/8	3.53	.994	1.27	1.42	1.060	1.040
1 3/16	3.73	1.107	1.41	1.67	1.089	1.059
1 1/4	3.93	1.227	1.56	1.95	1.118	1.077
1 5/16	4.12	1.353	1.72	2.26	1.146	1.095
1 3/8	4.32	1.485	1.89	2.60	1.173	1.112
1 7/16	4.52	1.623	2.07	2.97	1.199	1.129
1 1/2	4.71	1.767	2.25	3.38	1.225	1.145
1 9/16	4.91	1.917	2.44	3.82	1.250	1.161
1 5/8	5.11	2.074	2.64	4.29	1.275	1.176
1 11/16	5.30	2.236	2.85	4.80	1.299	1.191
1 3/4	5.50	2.405	3.06	5.36	1.323	1.205
1 13/16	5.69	2.580	3.29	5.95	1.346	1.219
1 7/8	5.89	2.761	3.52	6.59	1.369	1.233
1 15/16	6.09	2.948	3.75	7.27	1.392	1.247
2	6.28	3.142	4.00	8.00	1.414	1.260
2 1/16	6.48	3.341	4.25	8.77	1.436	1.279
2 1/8	6.68	3.547	4.52	9.59	1.458	1.286
2 3/16	6.87	3.758	4.78	10.47	1.479	1.298
2 1/4	7.07	3.976	5.06	11.39	1.500	1.310
2 5/16	7.26	4.200	5.35	12.36	1.521	1.322
2 3/8	7.46	4.430	5.64	13.40	1.541	1.334
2 7/16	7.66	4.666	5.94	14.48	1.561	1.346
2 1/2	7.85	4.909	6.25	15.63	1.581	1.358
2 9/16	8.05	5.157	6.57	16.83	1.600	1.369
2 5/8	8.25	5.412	6.89	18.08	1.620	1.380
2 11/16	8.44	5.673	7.22	19.41	1.639	1.391
2 3/4	8.64	5.940	7.56	20.79	1.658	1.402
2 13/16	8.84	6.213	7.91	22.25	1.677	1.412
2 7/8	9.03	6.492	8.27	23.76	1.695	1.422
2 15/16	9.23	6.777	8.63	25.34	1.714	1.432
3	9.42	7.07	9.00	27.00	1.732	1.442
3 1/8	9.82	7.67	9.77	30.52	1.768	1.462
3 1/4	10.21	8.30	10.56	34.32	1.803	1.482
3 3/8	10.60	8.95	11.39	38.44	1.837	1.500
3 1/2	11.00	9.62	12.25	42.88	1.871	1.518
3 5/8	11.39	10.32	13.14	47.63	1.904	1.535
3 3/4	11.78	11.05	14.06	52.73	1.936	1.553
3 7/8	12.17	11.79	15.02	58.17	1.968	1.570
4	12.57	12.57	16.00	64.00	2.000	1.587
4 1/4	13.35	14.19	18.06	76.78	2.061	1.619
4 1/2	14.14	15.90	20.25	91.93	2.121	1.651
4 3/4	14.92	17.72	22.56	107.16	2.179	1.681
5	15.71	19.63	25.00	125.00	2.236	1.710
5 1/4	16.49	21.64	27.56	144.70	2.291	1.738
5 1/2	17.28	23.76	30.25	166.37	2.345	1.765
5 3/4	18.06	25.97	33.06	190.11	2.398	1.792
6	18.85	28.29	36.00	216.00	2.449	1.817
6 1/4	19.64	30.68	39.06	244.14	2.500	1.832
6 1/2	20.42	33.18	42.25	274.63	2.550	1.866
6 3/4	21.21	35.78	45.56	307.55	2.598	1.890
7	21.99	38.48	49.00	343.00	2.646	1.913

Circumferences, Areas, Squares, etc., of Circles. Advancing by 16ths, 8ths and 4ths—1 to 50.

(Continued.)

Diameter or No	Circumference	Area	Square	Cube	Square √Root	Cube Root
7¼	22.78	41.28	52.56	381.08	2.692	1.935
7½	23.56	44.18	56.25	421.88	2.739	1.957
7¾	24.35	47.17	60.06	465.48	2.784	1.979
8	25.13	50.26	64.00	512.00	2.828	2.000
8¼	25.92	53.46	68.06	561.52	2.872	2.021
8½	26.70	56.75	72.15	614.12	2.915	2.041
8¾	27.49	60.13	76.56	669.92	2.958	2.061
9	28.27	63.62	81.00	729.00	3.000	2.080
9¼	29.06	67.20	85.56	791.45	3.041	2.098
9½	29.85	70.88	90.25	857.37	3.082	2.118
9¾	30.63	74.66	95.06	926.86	3.122	2.136
10	31.41	78.54	100	1000	3.162	2.154
11	34.55	95.03	121	1331	3.317	2.224
12	37.68	113.0	144	1728	3.464	2.289
13	40.84	132.7	169	2197	3.606	2.351
14	43.98	153.9	196	2744	3.742	2.410
15	47.12	176.7	225	3375	3.873	2.466
16	50.26	201.0	256	4096	4.000	2.520
17	53.40	226.9	289	4913	4.123	2.571
18	56.54	254.4	324	5832	4.243	2.261
19	59.69	283.5	361	6859	4.359	2.668
20	62.83	314.1	400	8000	4.472	2.714
21	65.97	346.3	441	9261	4.583	2.759
22	69.11	380.1	484	10648	4.690	2.802
23	72.25	415.4	529	12167	4.796	2.844
24	75.39	452.3	576	13824	4.899	2.885
25	78.54	490.8	625	15625	5.000	2.924
26	81.68	530.9	676	17576	5.099	2.963
27	84.82	572.5	729	19683	5.196	3.000
28	87.96	615.7	784	21952	5.292	3.037
29	91.10	660.5	841	24389	5.385	3.072
30	94.24	706.8	900	27000	5.477	3.107
31	97.59	754.8	961	29791	5.568	3.141
32	100.5	804.2	1024	32768	5.657	3.175
33	103.7	855.3	1089	35937	5.745	3.208
34	106.8	907.9	1156	39304	5.831	3.240
35	110.0	962.1	1225	42875	5.916	3.271
36	113.1	1017.9	1296	46656	6.000	3.302
37	116.2	1075.2	1369	50653	6.083	3.332
38	119.4	1134.1	1444	54872	6.104	3.362
39	122.5	1194.6	1521	59319	6.245	3.391
40	125.7	1256.6	1600	64000	6.325	3.420
41	128.8	1320.3	1681	68921	6.403	3.448
42	131.9	1385.4	1764	74088	6.481	3.476
43	135.1	1452.2	1849	79507	6.557	3.503
44	138.2	1520.5	1936	85184	6.633	3.530
45	141.4	1590.4	2025	91125	6.708	3.557
46	144.5	1661.9	2116	97336	6.782	3.583
47	147.7	1734.9	2209	103823	6.856	3.609
48	150.8	1809.6	2304	110592	6.928	3.634
49	153.9	1885.7	2401	117649	7.000	3.659
50	157.1	1963.5	2500	125000	7.071	3.684

WHITWORTH STANDARD THREADS.

Outside Diameter	Diameter at Bottom of Threads	Threads per Inch	Tapping Size	Outside Diameter	Diameter at Bottom of Threads	Threads per Inch	Tapping Size
1/32	.029	150	..	2 3/8	2.054	4	2 1/16
1/16	.041	60	3/64	2 1/2	2.180	4	2 3/16
3/32	.067	48	5/64	2 5/8	2.304	4	2 5/16
1/8	.093	40	3/32	2 3/4	2.384	3 1/2	2 13/32
5/32	.112	32	1/8	2 7/8	2.509	3 1/2	2 33/64
3/16	.134	24	9/64	3	2.634	3 1/2	2 41/64
7/32	.165	24	11/64	3 1/8	2.759	3 1/2	2 49/64
1/4	.186	20	3/16	3 1/4	2.856	3 1/4	2 55/64
5/16	.241	18	1/4	3 3/8	2.980	3 1/4	2 63/64
3/8	.295	16	19/64	3 1/2	3.105	3 1/4	3 1/8
7/16	.346	14	23/64	3 5/8	3.230	3 1/4	3 15/64
1/2	.393	12	13/32	3 3/4	3.320	3	3 21/64
9/16	.455	12	15/32	3 7/8	3.448	3	3 29/64
5/8	.508	11	33/64	4	3.573	3	3 37/64
11/16	.571	11	37/64	4 1/8	3.698	3	3 43/64
3/4	.622	10	5/8	4 1/4	3.804	2 7/8	3 13/16
13/16	.684	10	11/16	4 3/8	3.930	2 7/8	3 15/16
7/8	.732	9	47/64	4 1/2	4.054	2 7/8	4 1/16
15/16	.795	9	51/64	4 5/8	4.180	2 7/8	4 3/16
1	.840	8	27/32	4 3/4	4.284	2 3/4	4 19/64
1 1/8	.942	7	61/64	4 7/8	4.409	2 3/4	4 27/64
1 1/4	1.067	7	1 1/16	5	4.535	2 3/4	4 7/16
1 3/8	1.161	6	1 11/64	5 1/8	4.660	2 3/4	4 43/64
1 1/2	1.286	6	1 19/64	5 1/4	4 762	2 5/8	4 49/64
1 5/8	1.368	5	1 3/8	5 3/8	4.887	2 5/8	4 57/64
1 3/4	1.494	5	1 1/2	5 1/2	5.012	2 5/8	5 1/64
1 7/8	1.590	4 1/2	1 19/32	5 5/8	5.137	2 5/8	5 9/64
2	1.715	4 1/2	1 23/32	5 3/4	5.240	2 1/2	5 1/4
2 1/8	1.840	4 1/2	1 27/32	5 7/8	5.362	2 1/2	5 3/8
2 1/4	1.930	4	1 15/16	6	5.487	2 1/2	5 1/2

AMERICAN STANDARD THREADS.

(Sellers.)

Outside Diameter	Bottom Diameter	Threads per Inch	Tapping Size	Width of Flats	Outside Diameter	Bottom Diameter	Threads per Inch	Tapping Size	Width of Flats
1/4	185	20	3/16	.0062	2	1.712	4 1/2	1 23/32	.0277
5/16	240	18	1/4	.0074	2 1/4	1.962	4 1/2	1 31/32	.0277
3/8	294	16	19/64	.0078	2 1/2	2.176	4	2 3/16	.0312
7/16	.345	14	23/64	.0089	2 3/4	2.426	4	2 7/16	.0312
1/2	.400	13	13/32	.0096	3	2.629	3 1/2	2 41/64	.0357
9/16	454	12	15/32	.0104	3 1/4	2.879	3 1/2	2 57/64	.0357
5/8	.506	11	33/64	.0113	3 1/2	3.100	3 1/4	3 7/64	.0384
3/4	.620	10	5/8	.0125	3 3/4	3.317	3	3 21/64	.0413
7/8	731	9	47/64	.0138	4	3.567	3	3 37/64	.0413
1	837	8	27/32	.0156	4 1/4	3.798	2 7/8	3 13/16	.0435
1 1/8	.939	7	61/64	.0178	4 1/2	4.028	2 3/4	4 1/32	.0454
1 1/4	1.064	7	1 5/64	.0178	4 3/4	4.256	2 5/8	4 17/64	.0476
1 3/8	1.158	6	1 11/64	.0208	5	4.480	2 1/2	4 31/64	.0500
1 1/2	1.283	6	1 19/64	.0208	5 1/4	4.730	2 1/2	4 47/64	.0500
1 5/8	1.389	5 1/2	1 25/64	0227	5 1/2	4.953	2 3/8	4 61/64	.0526
1 3/4	1.491	5	1 1/2	.0250	5 3/4	5.203	2 3/8	5 13/64	.0526
1 7/8	1 615	5	1 5/8	.0250	6	5.423	2 1/4	5 7/16	.0555

BRITISH ASSOCIATION THREADS.

(B.A.)

B.A. Nos	Outside Diameter	Bottom Diameter	Threads per Inch	Tapping Drill No.	B.A Nos	Outside Diameter	Bottom Diameter	Threads per Inch	Tapping Drill No.
0	236	.188	25 4	12	13	047	.035	102	65
1	209	168	28 2	19	14	039	.028	110	70
2	185	147	31 4	26	15	035	025	121	72
3	161	127	34 8	30	16	031	.022	133	74
4	142	111	38 5	34	17	028	.020	149	75
5	126	098	43 0	39	18	024	017	169	76
6	110	085	47 9	44	19	021	015	182	78
7	098	076	52 9	47	20	019	013	213	80
8	087	066	59.1	51	21	017	.011	233	..
9	075	057	65 1	53	22	015	010	257	..
10	067	050	72 6	55	23	013	.009	286	.
11	059	.044	81 9	56	24	011	.008	323	..
12	.051	.038	90 7	62	25	010	.007	357	..

TABLE — Weight of Substances

Substance	Specific Gravity	Weight in Lbs. Cub. In.	Weight in Lbs. Cub. Ft.
METALS			
Platinum, Rolled	23.0	.828	1436.0
Platinum	21.5	777	1342.0
Gold, 24 Carat	19.32	.698	1206.0
Gold, Standard	17 724	.638	1106.0
Mercury	13.58	.490	847.4
Lead	11.37	411	709.8
Silver	10.53	.380	657.1
Copper, Rolled.	8.93	.3222	556.8
Copper, Pure	8.82	.3186	550.6
Nickel	8.80	.318	549.3
Bronze	8.75	.316	546.2
Cadmium	8.6	.8105	538.2
Brass Cast	8.4	.303	524.0
Manganese	8.0	.289	499.4
Steel	7.80	.2816	486.7
Iron, Wrought.	7.70	.278	480.1
Tin	7.29	.263	455.1
Iron, Cast	7.22	.260	450.0
Zinc, Rolled	7.19	.258	448.9
Zinc, Cast	6.86	.248	428.3
Antimony	6.71	.2424	418.9
Aluminium, Rolled	2.68	.0967	167.1
Aluminium, Cast	2.56	.0924	159.6
Magnesium	1.74	.063	108.6

Substance	Specific Gravity	Weight in Lbs. Cub. In.	Weight in Lbs. Cub. Ft.
SOLIDS			
Emery	4.0	1446	250.0
Cement, Portland	3.1	1123	194.0
Slate	2.8	1012	175.0
Mica	2.8	1012	175.0
Granite	2.6	0927	160.0
Quartz	2.6	.0944	163.0
Brick, Fire	2.3	.0834	144.0
Sandstone	2.2	.0811	140.0
Concrete	2.2	0811	140.0
Ivory	1.85	0666	115.0
Brick, Common.	1.8	0648	112.0
Phosphorus	1.8	.0648	112.0
Plaster of Paris	1.8	.0648	112.0
Ice	0.91	0324	56.0
Coal, ordinary loose	0.91	0324	56.0

Substance	Specific Gravity	Weight in Lbs. Cub. In.	Weight in Lbs. Cub. Ft.
LIQUIDS			
Fluoric Acid	1.5	.0542	93.6
Carbon Disulphide	1.26	.0465	76.6
Nitric Acid	1.22	.0441	76.1
Water	1.00	.0361	62.3
Linseed Oil	0.94	.0339	56.6
Olive Oil	0.92	.0332	57.4
Ammonia	0.89	.0322	55.5
Alcohol, pure	0.79	.0285	49.25
Naptha	0.76	0.274	47.4
Ether	0.72	.0260	44.8
Petrol	0.70	.0252	43.6
Benzene	0.69	.0249	43.0

Substance	Specific Gravity	Weight in Lbs. Cub. In.	Weight in Lbs. Cub. Ft.
WOOD			
Ebony	1.25	.045	78.0
Lignum Vitae	1.10	.040	68.5
Mahogany	0.90	.032	56.3
Teak	0.85	.030	53.0
Oak	0.80	.029	49.9
Ash	0.75	.027	46.8
Beech	0.75	.027	46.8
Cypress	0.60	.022	37.5
Cedar	0.57	.021	35.5
Pine, White	0.50	.018	31.3
Cork	0.25	.009	15.0
GLASS			
Dense Flint	3.6	.1297	224.0
Light Flint	3.0	.1082	187.0
B.S.C	2.54	.0915	158.0
Hard Crown	2.48	.0897	155.0

BRITISH WEIGHTS AND MEASURES

LENGTH

12 inches	=	1 foot	1 chain	=	22 yards
7.92 inches	=	1 link			100 links
3 feet	=	1 yard	40 rods	=	1 furlong
2 yards	=	1 fathom	8 furlongs	=	1 mile
$5\frac{1}{2}$ yards	=	1 rod, pole or perch	1 mile	=	80 chains 320 rods 1,760 yards
4 rods	=	1 chain			

AREA

144 square inches	=	1 sq. foot	40 sq. rods	=	1 rood
9 square feet	=	1 sq. yard	4 roods	=	1 acre
$30\frac{1}{4}$ square yards	=	1 sq. rod	640 acres	=	1 sq. mile

BRITISH WEIGHTS AND MEASURES (Continued)

VOLUME

1 cubic inch	=	·000578 cubic foot	1 cubic foot	=	·0370 cubic yards
1,728 cubic inches	=	1 cubic foot	27 cubic feet	=	1 cubic yard
4 gills	=	1 pint	2 gallons	=	1 peck
2 pints	=	1 quart	4 pecks	=	1 bushel
4 quarts	=	1 gallon	8 bushels	=	1 quarter

WEIGHT

27·3 grains	=	1 dram	4 quarters	=	1 hundredweight
16 drams	=	1 ounce		=	112 pounds
16 ounces	=	1 pound	20 hundredweight	=	1 ton
14 pounds	=	1 stone		=	2,240 pounds
28 pounds	=	1 quarter			

TABLE OF BRITISH AND METRICAL EQUIVALENTS

BRITISH TO METRICAL				METRICAL TO BRITISH		
LENGTH						
1 inch	=	25·4	millimetres	1 millimetre (m.m.)	=	0·03937 inch
1 foot	=	30·4799	centimetres	1 centimetre = 10 m.m.	=	0·3937 inches
1 yard	=	0·9143	metre	1 metre		39·37 inches 3·280 feet 1·093 yards
1 fathom	=	1·8288	metre			
1 chain	=	20·1168	metres	1 kilometre	=	1000 metres
1 furlong	=	201·168	metres		=	3280·9 feet
1 mile	=	1·6093	kilometres			
AREA						
1 sq. inch	=	6·4516	sq. centimetres	1 sq. centimetre	=	0·155 sq. ins.
1 sq. foot	=	929·03	sq. centimetres	1 sq. metre	=	10·7639 sq. feet
	=	·092903	sq. metre		=	1·196 sq. yards
1 sq. yard	=	·8631	sq. metre	100 sq. metres	=	1 are
1 acre	=	·40468	sq. hectares	1 are	=	119·60 sq. yards
1 sq. mile	=	59 hectares		1 hectare	=	2·4711 acres

BRITISH AND METRICAL EQUIVALENTS (Continued)

VOLUME

1 cubic inch	=	16·387 cub. centimetres	1 cubic centimetre	=	0·061 cub. in.
1 cubic foot	=	0·028317 cub. metre	1 cubic decimetre	=	61·024 cub. ins.
1 cubic yard	=	0·764553 cub. metre	1 cubic metre	=	35·3148 cub. feet
				=	1·3079 cub. yd.
1 pint	=	·568 litre	1 centilitre	=	0·0704 gills
1 quart	=	1·136 litres	1 decilitre	=	0·1759 pints
1 gallon	=	4·5459 litres	1 litre	=	1·7598 pints

WEIGHT

1 dram	=	1·7719 gramme	1 centigramme	=	0·1543 grain
1 ounce	=	28·35 grammes	1 gramme	=	15·4323 grains
1 pound	=	453·592 grammes	1 kilogramme	=	2·2046 pounds
1 hundredweight	=	50·802 kilogrammes	1 quintal	=	110 kilogrammes
		0·508 quintal		=	1·968 cwt.
1 ton	=	1016 kilogrammes	1 tonne	=	1000 kilogrammes
		1·016 tonnes		=	·9842 tons

INDEX

Roman numerals indicate pages.

Italics indicate illustrations.

ABRASIVES, 319, 320
  artificial, 320
  natural, 320
Acetone, 33
Acetylene gas, 33
  dissolved, 33
  production of, 33
Acid, hydrochloric, 20, 21, 171, 337
  muriatic, 20, 22
  nitric, 102, 336, 337
  sulphuric, 171
Acme thread, 200, *200*
  uses of, 200
Addendum, 279, 280
  circle, 279, *280*
Adjustable, hacksaw, 93, 94, *94*
  spanners, 213, *215*, 215
Allowances, 220
  British Standard, 220
  American Standard, 221
  definition of, 220
  degrees of, 221
  formula for, 222
Alloying, effects of, 157
Alloying elements, 148, 149, 150
  characteristics, 148, 149, 150
  properties, 148, 149, 150
Alloys, 159
  aluminium, 160, 162
  antimony, 160, 162
  characteristics, 153, 154
  fusible, 159
  copper-tin, 158
  copper-zinc, 158
  groups, 157
  intermetallic, 172
  properties, 157
  tin-lead, 159
  uses of, 153, 154
Alloy Steels, 148
  characteristics, 148
  properties, 148
  uses of, 148
Aloxite, 320
Alumina, 37, 330
Aluminium, 42, 311
  alloys, 160
  bronze, 160
  oxide, 320
  protection of, 31
  soldering, 30
  solders, 31
Alundum, 320
American standard "V" thread, 198, *198*
Ammonium chloride, 21, 171, 172
Angle gauge, 104
Annealing, 43, 163, 317, 331
Antimony, 153
  alloys, 157, 160
  characteristics, 153
  properties, 153
  uses of, 153
Anvil, 286, *287*
Arc welding, 38
Area of circles, 379, 380-381
Art Metalwork, 331
  design, 331
Ash, 70
Atomic particles, 167
Autogenous welding, 32

BABBITT'S METAL, 160
  composition, 160
  properties, 160
  uses, 160
Back gear, *226*, 226

Bars, folding, 50, *50*
merchant, 140
puddled, 140
Basic electric furnace, 144, 145
Bauxite, 320
Bearings, 274
machinery, 160
types of, 274
self-oiling, 274, *275*
Beds, lathe, 225
cinder, 313
Bells, 158, 301
castings, 158
Belts, Pulleys and Power Transmission, 266
Belts, 266
arc of contact, 269, *269*
care of, 266
classification, 266
definition of, 266
dressing, 267
fastening devices, 268, *268*
materials, 266
methods of using, 269, *269*, *271*
Bench, shears, 13, *13*
lathe, *231*
Bending, 291, 294
Bessemer, Converter, 140, *141*
process, 140
steel, 141
Bevel, 103
gears, 280
sliding, 103
plan of, 330A
Bismuth, 23, 24, 157
Black Prince, 315
Blast Furnace, 136
diagrammatic arrangement, *138*A
operation of, 136, 137
"Blind" hole, 204
Blister steel, 144
Blooms, 139
Blowpipe, 28, 32
welding, 33
Board, filing, *64*, 64-65
Bolster, 55
Bolts, Nuts and Screws, 187
Bolts, classification, 187
types of, 187-189, *187-189*
Borax, 27, 28, 29, 239
Box spanners, 215
set of, 215
uses of, 215
Box square, *116*, 116
uses of, 116
Brass, 43, 158
annealing, 163
colouring, 337
composition, 158
moulding, 315
steps in, 315, 316
properties, 158
uses, 158
Brazing, 27
blowpipe, 28
flux, 27
heat, 28
method of, 28
spelters, 28
"Breaking-up" a surface, 75, *75*
Brine, 164
"Brinell" hardness, 131
Britannia metal, 153
British Association thread, 199, *199*
uses of, 199
standard "V" thread, *197*, 198
uses of, 198
Brittleness of metals, 133
Bronze, 158
aluminium 160
composition of, 158
pillars, 301
statuary, 158, 315
uses of, 158
Brush, file, *86*, 86
Buffing, 337
Buttress thread, 200, *200*
uses of, 200, *201*
Buttweld, 37

CADMIUM, 173
Caliper gauge, 105
Calipers, 122
classification, 126
parts, 126
setting the, 124, *124*
types, *122*, 125, 126, *126*
using the, 123, 124
uses of, 123
Calorising, 172

Cap Screw, 189, *189*
Carbide of calcium, 33
composition of, 33
Carbide, silicon, 320
Carbides, cemented, 151
Carbolite, 320
Carbon Steel, 150
characteristics, 150
Carborundum, 320, 322
Carriage bolt, *189*, 189
uses of, 189
Carriers, lathe, *232*, 232
Case-hardening, 163, 166
methods of, 166
nitrogen, 166, 167
uses of, 166
Castle nut, *193*, 193
uses of, 193
Castings, annealing of, 317
steel, 36, 303
Cast Iron, 136, 138
characteristics, 138
properties, 138
malleable, 138-139
uses, 138
Cast Steel, 11, 143
Cementation, furnace, *143*
process, 143-144
Cemented carbides, 151
characteristics, 151
composition, 151
uses of, 151, 238, 251
Centigrade, 132, 145
Centre, drill, *179*, 179
gauge, 104
lathe, *228*, 228
punch, 103
square, 115
using the, *115*
"Castle" nut, *193*, 193
Change wheels, 227
Charcoal, granulated, 33
Chasers, screw, 237
use of, 237, *237*
Check nuts, 192
Chisels, cold, 74
classification, 74, 78
cutting angles of, 76, *76*
lubrication of, 77
methods of holding, *77*
parts, 78
Chisels—*continued.*
types, 74, 78
uses of, 12, 74, 78
Chloride, ammonium, 21, 171, 172
zinc, 18, 20
Chrome, 147, 148
characteristics, 148
ferro, 146, 150
properties, 148
uses, 148
Chromium plating, 173
Chucks, drill, 234
lathe, 233, *233*, *234*
Circular Pitch, 279, *280*
Circumference of circles, 380-381
Clamps, 256, *256*
vice, 63, *63*
toolmakers, 63, *63*
drill block, 63, *63*
using the, 260, *260*
Clamping, block, *257*, 258
bolts, 256, *257*
Clay, China, 306
fire, 37
Cleaners, moulders, 307, *307*
Cleansing fluxes, 20
Clearance angle, drills, 175
lathe tools, 234
shaper tools, 251
Clutch, pulley, 273, *273*
function of, 273
Coal, 285, 286
dust, 305
"green", 286
Cobalt, properties, 149
characteristics, 149
Co-efficient of expansion, 133
Coke, 28, 136, 286, 304, 320
Cold set, 288, *288*
Collet spanner, 216, *217*
uses of, 216, 217
Colour of metals, 128
Colouring of Metals, 337, 338
Combination centre, drill, *179*
use of, 179
square, 115, *115*
uses of, 115
Compasses, wing, 119, *119*
Compression of metals, 132
Conductivity of metals, 131

Cone, development of *344*, 344
truncated, development of, *345*, 345
Construction, 325
steps in, 325
making the calipers, 326
a scoop, 328
Contact weld, 37
Contraction, 332
Cope, 308
Copper, 42, 154
annealing, 154, 163
characteristics, 154
colouring, 337
finishing, 336, 337
plating, 173
polishing, 337
properties, 154
soldering bit, 15
sulphate, 101
uses, 154
wire drawing, 130
Copper-zinc alloys, 157, 158
tin alloys, 157, 158
Core making, 310, 311
Corrosion, 42, 68, 151
auto, 31
resisting alloy, 151
Corundum, 320
Covered metals, 40
Cover washer, *194*, 194
Countershaft, 226
Counterboring, *178*, 179
Couplings, 273
compression, 274, *274*
flanged, 273, *274*
Crank Drive (shaper), 245
Cross filing, 85
method of, *85*
Crucible, furnace, 303, 304, *304*
materials used, 304
operating the, 304
cast steel, 144
Crucibles, 304
capacity of, 304
Cube, development of, *339*, 339
root, 380-381
Cup-head bolt, *189*, 189
Cupola, *302*, 302-303
charge, 303
preparation, 303
Cupola—*continued.*
tapping, 303
capacity of, 303
Curved snips, 12, *12*
Cutter bar, *180*, 180
Cutting metals, 36
forgework, 295, 296
oxy-acetylene process, 36
Cutting steels and Alloys, 150
Cyanide, potassium, 166
case-hardening, 166
Cylinder, development of, *342*, 342

DATA for gearing, 279
Davy, Sir Humphrey, 33
Dead centre, 228, 241
Decimal equivalents, 377
Dedendum, 279, *280*
Definition of—
a belt, 266
allowance, 220
limit, 220
tolerance, 220
Degrees of allowance, 221
Depth gauge, 104, 115
Design, art metal work, 333
Developments, 339-348
cone, *344*, 344, 345
cube, *339*, 339, 340
cylinder, *342*, 342
hexagonal prism, *341*, 341
scoop, *343*, 343, 344
square prism, *340*, 340
square pyramid, *346*, 346, 347
truncated cone, *345*, 345, 346
truncated square pyramid, *347*, 347, 348
Dies, details of, *209*, 209, 210, *210*
humouring of, 211
lubrication of, 211
Dividers, 118
setting the, 119, *120*
spring, 118, *118*
uses of, 119
using the, 119
Dolomite, 145
Double ended spanner, *213*, 213
Drag, 308
Drawfiling, 85
method of, *86*
Drawing-down, 291, 294

"Drawing-over" a hole, 75, 184
steps in, *184*
Dresser, emery wheel, 322, *322*
tinman's, *46*
Dressing, belts, 267
moulds, 305
Drift, 55
Drill chuck, 182
Drilling, 175
cutting speeds, 185
lubricants, 186
points to be observed, 184
Drilling Machines—
types of, 181-183
bench, 181, 182, *182*
breast, 181, 183, *183*
floor, 181, 182
hand, 181, 183, *183*
radial, *181*
ratchet, 176, *183*
wall, 181, 183
Drills and Drilling, 175
Drills—
centre, *179*, 179
countersinking, *180*, 180
flat, *177*, 177-178
flat-ended, *179*, 179
pin or counter bore, *178*, 178-179
straight-fluted, *178*, 178
twist, 175-177, *175-177*
Drive, belt, *271*, 275
gear, *271*, 278
friction, 278
Driver, stud, 190, *190*, 191
Drop forging, 213
Ductility of metals, 130
Duralumin, 160
composition, 160
properties, 160
uses, 160

EDGES, types of, 55
finishing, 55
Elastic limit, 133
Elasticity, of metals, 133
modulus of, 133
Electrical conductivity of metals, 131
Electric arc furnace, 144, *145*
acid type, 145
Electric arc furnace—*continued.*
basic type, 145
capacity of, 145
Electric, high frequency furnace, 146, *146*
induction furnace, 146
acid type, 146
basic type, 146
capacity of, 147
lamp, 149
steel, 143, 144
process of making, 144
welding, 37
arc, 38
resistance, 37
types of, 37
Electrode, 38
Electroplate, 173
Elektron metal, 161
Emerald, 148
Emery, 320
cloth, 87, 242, 337, 338
powder, 324
wheels, 320
hand, 320, *320*
power, 320
Engineer's square, 112
Expansion of metals, 133
co-efficient of, 133
External threads, 203
Extractor, stud, 191, *190*
Eye bolt, 188, *188*
Ezy-out stud extractor, *190*

FACE, gear, 279, *280*
Fahrenheit, 132
Fastenings, 187
belt, 268, *268*, 269
Feeds for tools, 242, 250
Feeler gauge, 105
Ferrous metals, 136
chart, 135
Fettling, 139
Files and Filing, 79
Files, brush, *86*, 86
classification, 87
cut, 81, *81*
grade, 82, *82*
length, 79
manufacture, 79
parts, 87
polishing with, 87

Files—*continued.*
shape (sectional form), 79, *79*
use of, 80-81
using, 83
Filing, methods of, 85 86, *85-86*
lathe work, 242
Finishing and Polishing, 336
brass and copper, 336, 337
buffing, 337
colouring, 337
lacquering, 337
pickling, 336, 337
polishing, 336-337
iron and steel, 337-338
colouring, 338
polishing, 337-338
tinplate, 336
Fire, bricks, 137, 302
clay, 37
irons, *286*, 286
welding, 32
Fits and Tolerances, 218
Fits, classification, 218
American Standard, 219
British Standard, 218
definition of, 218
groups, 218-219
Fixtures, shaper, 255
Flank, 279, *280*
Flat ended drill, *179*, 179
uses of, 179
Flat, drill, *177*, 177
key, *195*, 195
square, 114, *114*
uses of, 114
Flatter, *290*, 290
Fluorspar, 146
Fluxes, 20, 293
brazing, 27-28
classification, 20
cleansing, 20
forgework, 293-294
pig iron, 136
preparation of, 20
protective, 20
soldering, 21, *21*
uses of, 21
welding, 36
Folding bars, 50, *50*
Forge, 284
types of, 284
hand, *285*
Forgework, 284
exercises, 373
fire, 284-285
cleaning of, 286
irons, 286, *286*
oxidising, 285
reducing, 285
fluxes, 293-294
fuels, 286
heats, 292-293
operations, primary, 291
secondary, 292
theory examinations, 266-269
tools, 286-291
Forging, definition of, 284
drop, 213
Formulae for calculating—
diameter of shafts, 276
horsepower, 276
speeds of gearing, 279
pulleys, 276
shafts, 276
weight of brass and copper sheets, rods and bars, 379
Founding, 301
Friction drive, 278
Fuels, 136, 286
Fullers, top, *290*, 290
bottom, *290*, 290
Funnel, plan of, *330B*
Furnace, Bessemer, 140-141, *141*
blast, 136, *138A*
cementation, 143, *143*
crucible, 144, 304, *304*
cupola, *302*, 302-303
electric, arc, 144, *145*
induction, 146
open hearth, 141-142; *142*
puddling, *139*, 139-140
tapping the, 137
Fusible alloys, 159
uses of, 159
Fusibility of metals, 132

GALLIPOLI Oil, 21
Galvanic cells, 31
Galvani, Luigi, 170
Galvanised iron, 40
manufacture, 171
uses of, 171
Galvanising, 171

Ganister, 145
Gauges, 104
angle or centre, 104, *104*
Birmingham, 41, 43
caliper or snap, 105, *105*
depth, 104, *104*
drill, 107, *107*
feeler, 105, *105*
lead, 44
plug, 104, *105*
radius, 106, *106*
ring, 105, *105*
screw pitch, 107, *107*
wire, *43*, 44
zinc, 44
Gauging sheet metals, 43
Gear, bevel, 280
drive, *271*, 278
shaper, 246
intermediate, 271, 282
spur, 280
Gearing, data and formulae—
for calculating, 279
speeds of, 279
problems, 280-282
Gib-head key, 196
Gold, 154
characteristics, 154
properties, 154
uses of, 154
Graphite, 306
Green Sand moulding, 309-310
Grinding and Sharpening, 318
Grinding wheels, 319-320, *320*
care of, 322
dresser, 322, *322*
grades, 321
grain or grits, 321-322
guards, 322
speeds of, 320-321
Grindstones, 318, *318*
care of, 318-319
speeds of, 319
using the, 318
Groover, 54, *54*

HAEMATITE, 139
Hachures, standard, *376*
Hacksaws, 93
classification, 99
Hacksaws—*continued.*
blades, 93, *93*, *94*, *95*
number of teeth, 95
slotting, 95, *95*
types, 93, *93*, 94, *94*
holding the, 95, *96*
parts, 93
piercing, *98*, 98
using the, *98*
types of, 99
Hammers, 69, *69*, 72, 288
ball-pane, 69
classification, 72
cross-pane, *69*
fitting the handle, 71, *71*
paning, 70, *70*
parts, 69-70
planishing, 70, *70*
repoussé, 70, *70*
set, 290, *290*
sledge, 71-72, *72*, *288*, 288
straight pane, 69
types of, *69*, 72
uses of, 70, 71, 73
using the, 71
weight of, 72
Hardening, 163, 164
case, 166-167
Hardie, 289
Hardness of metals, 130-131
Hatchet bit, 15, *16*
Headstock, 225-226, *226*
Heat conductivity, 131
Heating, induction, 167-168, *168*
Heat treatment of metals, 163
Heats, forgework, 292-293
Hermaphrodite calipers, 123
Heterogeneous welding, 32
Hickory, 70, 73
Hiduminium, 160
High speed steel, 150
characteristics, 150
uses of, 150
Hook bolt, 188, *188*
Horsepower, 275
calculation of, 276
of belts, 275
Hot set, *288*, 288
Hydrochloric acid, 20, 171
Hypo, 337, 338

INDUCTION heating, 167 168
machine, *168*
Ingot moulds, 142, 146
Iron, annealing, 163
cast, 136, 138
characteristics, 138
colouring of, 338
galvanised, 40-41, 170-171
malleable cast, 138-139
manufacture of, 136-137
moulding, 302, 305, 306
ore, 136
pig, 137, 138
properties, 137, 138
wrought, 139-140
Inside, calipers, *122*, 123, 126
micrometer, *126*
Intermediate gears, 271, *282*
functions of, 282
Intermetallic alloys, 172
Internal threads, 203

JAGGED bolt, *188*, 188
Jenny calipers, 127, *122*, 123
Jeweller's blowpipe, *29*
saw, 98
Jigs, shaper, 255-256
Jointing, 313-314
Jumping up, 291, 294-295

KALSOMINE, 101
Kerosene, 186, 250
Keys, 195-196
methods of fitting, 195
types of, *196*
uses of, 195-196
Keyways, 195
Killed spirits, 20-21, 22
King Solomon, 301
Knurling, examples of, *237*
tools, *237*, 238

LACQUERING, 337
"Land," *175*, 176
Lathes and Lathework, 225
accessories, 232-234
back gearing, 226-227
bench, *231*
boring in the, 241
carriage or saddle, 228-229, *229*
apron, 228-229, *229*
Lathes and Lathework—*contd.*
carriage or saddle—*contd.*
pinion, 229, *229*
rack, 229, *229*
carriers, *232*, 232
centres, 226, 228
changes of speed, 226-227
change wheels, 227
chucks, 233-234
drill, 234
independent, *233*, 233
self-centering, *233*, 233
magnetic, *234*
clearance angle of tools, 234
construction of, 225
drilling in the, 240-241
faceplate, 232
floor, *231*
headstock, 225-226, *226*
leadscrew, 200, 227, 230, 231
mandrel, *226*, 226, 227
tailstock, *227*, 228
screw cutting, 241
tools, 236
slide rest, 230
parts, 230
using the, 230-232
tool holders, 238, *238*, 251
tools, characteristics, 234
tipping of, 238-239
types, 234, *235*, *236*
uses, 234-238
work, 239
filing, 242
lubrication of, 243
polishing, 242
speed of, 241-242
types of, 239-241
Lead, 42, 153, 154
annealing, 164
burning, 36
characteristics, 42, 154
gauge, 44
properties, 42, 154
uses, 42, 154
Lime, 146, 147
Limestone, 136, 137, 337
Limit, definition of, 220
elastic, 133
Limits of tolerance, 220
Loam, moulding, 305
Lock-Joint calipers, 125, *125*

Lock nuts, 192
method of using, *192*, 192-193
Lubricants, 186, 243, 250
Lug washer, 195

MACHINE bolt, 187, *187*, 188
parts, 187
proportions of, 188
types, 188
uses, 188
screws, 191-192, *192*
types, 192
uses, 191
spanners, 213
Magnesite, 145, 146
Magnalium, 161
Magnesium, 37, 160
Malleability of metals, 130
Malleable cast iron, 138-139
production of, 138-139
uses of, 138
Mallets, classification, 46
egg-ended or bossing, 46, *46*
flat or straight faced, 45, *45*
parts, 46
types, 45-46
uses, 45, 46, 47
Manganese, 34, 149, 160
characteristics, 149
properties, 149
Maple, 334
Marking off, Measuring and Testing Tools, 101
Marking-off, 101
table, 109
Melting point of metals, 132
Mercury, 154
characteristics, 154
properties, 154
uses, 154
Merchant bar, 140
Metal Spraying, 172-173
Metals, alloyed, 42-43
brittleness, 133
characteristics, 128
colour, 128, 134
colouring, 337, 338
conductivity, 131, 134
compression, 132
covered, 40-41
ductility, 130, 134
Metals—*continued.*
elasticity, 133
expansion, 133
ferrous, 136
fusibility, 132, 134
hardness, 130-131, 134
malleability, 130, 134
manufacture, 136-137, 139-141, 143-145
non-ferrous, 153
ores, 136
plasticity, 133
properties, 128
shearing strength, 130
sheet, 40-43
specific gravity, 128
tempering, 164
tenacity, 129, 134
toughness, 133
weight, 128-129, 134
weldability, 133
Metalwork examinations
theory, 360-366
practical, 370-375
Micrometer, outside, 126, *126*
inside, 126, *126*
Mild Steel, 40, 140
characteristics, 40, 142
manufacture, 140-142
Bessemer converter, *141*
process, 140-141
Open Hearth furnace, *142*
process, 141-142
properties, 40, 142
uses of, 40, 142
Mixer, 137, 142
Modulus of elasticity, 133
Molasses, 310, 311
Molybdenum, 149
characteristics, 151
properties, 149
uses, 151
Monel Metal, 30, 151
characteristics, 151
composition, 151
properties, 151
uses, 151
Morse taper key, *196*
Motor, electric, 246
Moulding and Casting, 301
application of, 301
boxes, 308, *308*

Moulding and Casting—*continued.*
brass, 304, 315-316
contraction, 312
cores 310-311
cupola, *302*, 302-303
divisions of, 309
dry sand, 310
green sand, 309
gates, 314-315
history, 301
iron, 302-305
jointing, 313-314
metals, 301-304
non-ferrous metals, 304
patterns, 311-312
pouring the metal, 314
ramming, 312-313
risers, 314-315
runners, 314-315
sand, 305
shrinkage, 312, 317
steel, 303, 316-317
tools, 306-308
venting, 313
Moulds, ingot, 142, 146, 147
Muntz metal, 43, 158
composition, 43, 158
properties, 43, 158
uses, 43, 158
Muriatic acid, 20, 22

NICKEL, 148
characteristics, 148
properties, 148
steel, 30
Nitric Acid, 102, 336
Nitrogen case-hardening (nitriding), 166-167
Non-ferrous metals, 153
characteristics, 153-155, 156
properties, 153-155, 156
uses, 153-155, 156
Nut locking devices, 192-195, *192-195*
Nuts, 188
proportions of, 188
"quick," 118, *118*

OAK, Silky, 334
Odd-leg calipers, *122*, 123
Oil, cooling, 164
olive, 20, 21
Oilstones, 90, 119, *322*
care of, 324
slips, *323*, 323
truing, 324
using, 323-324
Open-hearth furnace, *142*, 303
process, 141-142
Ores, crushing, 136
iron, 136-137
washing, 136
Outside calipers, *122*, 123
Oxy-acetylene blowpipe, 32
diagram, *33*
flame, 32, 33
temperatures of, 33, *34*
welding, 30, 32
Oxy-coal gas welding, 32, 36
Oxygen, compressed, 33
Oxy-hydrogen welding, 32, 36

PANES, hammer, 69, 72
Parallels, *254*, 254
degree, *254*, 254
Patterns, 311, *311*
Petroleum Jelly, 21, 338
Pewter, 21, 22, 159
composition, 159
properties, 159
uses, 159
Pewterer's solder, 23, 24
Phosphorus, 34, 145
Pickling, 170, 171, 172
Piercing saw, 98, *98*
Pig Iron, 136-137, 138, 139
characteristics, 138
classification, 137
composition, 138
grey, 137, 138
mottled, 138
smelting, 136
white, 137, 138
uses of, 137, 138
Pin drill, *178*, 178-179
uses of, 179
Pinning, 86
Pin spanner, *216*, 216
uses of, 216
Pitch circle, 279, *280*
diameter, 279, *280*
point, 279, *280*

Pitch, screw threads, 198, 199, 200
Plating, chromium, 173
cadmium, 173
copper, 173
electro, 173
nickel, 173
Platinum, 155
characteristics, 155
properties, 155
uses, 155
Plastic compounds, 133
Plasticity of metals, 133
Plug gauge, 104, *105*
Plumbago, 310
Plumber's metal, 23
Pliers, 67
parallel jaw, 67, *68*
types of, 67, *67*
uses of, 68
Polishing, 87, 242, 336, 338
lathe work, 242
Potash, prussiate of, 166
Potassium cyanide, 166
Power transmission, 275
belt drive, *271*, 275
gear drive, *271*, 278
horse power, 275, 276
Practical problems—
tests A to Z, 349-359
"Primus" blowlamp, *16*
Prism, hexagonal,
development of, *341*, 341
square,
development of, *340*, 340
Properties of Metals, 128
Protective fluxes, 20
Puddled bar, 140
Puddling furnace, *139*, 139-140
process, 140
Pulley, 270, 272, *272*
clutch, 273, *273*
cone, 226
groups, 270
mandrel, 226
materials, 270
split, 270
types, 270, 272
whole, 270
Punches, centre, 103, *103*
uses of, 103
Punches—*continued.*
forgework, *291*, 291
repoussé, 333
Punching, 295
Pyramid, square,
development of, *346*, 346, 347
truncated square,
development of, *347*, 347, 348

QUARTZITE, 416

RADIUS gauge, 106, *106*
Raising an Ash-tray, 331-333
steps in procedure, 331-333
forming, *332*
finishing, 334
pickling, 334
Rammers, moulding, 307-308
bench, 308
floor, 307
Rasp, *81*, 81-82
Ratchet drill, 176, *183*
Reamers, 180, *180*, 181
uses of, 181
Recessed hole, 178
Reddle, 92, 110
Refractory, 302, 305
Repoussé hammer, *70*, 70-71, 333
punches, 333
work, 154, 158, 333
Resin, 20, 21, 133
Ring gauge, *105*, 105
uses of, 105
Ring spanner, 216
types, *216*
uses, 216
Rivet set, 54, *54*
Rods, welding, 34
Root circle, 279, *280*
Ruby, 148
Rule, key-seat, 116, *116*
steel, 102, *102*

SAL-AMMONIAC, 20, 21, 294
Sand, moulding, 305, 315
dry, 310
green, 309
Sawdust, 311
Saws, hack, 93, *93*, *94*
piercing, 98, *98*

Scrapers, 89
holding the, 90, 91
types, 89, *89*
sharpening, 90, *90*
use of, 89, 92
using the, 91-92
Screw chasers, 237
use of, 237, *237*
cutting, 241
hand, 203
in the lathe, 241
tools, 236-237
plate, 211
Screws, classifications, 187
machine, 191, *192*
set, 191, *191*
uses of, 187
Scriber, 102, *102*
use of, 103
Scribing block, 108, *108*
use of, 109
Seams, Joints and Edges, 51
Seams, 51
angle, 57
flat, 57
riveted, 54-55
types of, *52-53*
Seam weld, 37, 38
Sellers thread, 198, *198*
use of, 198
Set, cold, 288, *288*
hammer, 290, *290*
hot, *288*, 288
rivet, *54*, 55
screws, 191, *191*
types, 191
uses of, 191
seam, 54, *54*
Shafting, 273
material, 273
cold rolled, 273
turned, 273
Shaper, accessories, 253
Shaping machine, 245
accessories, 253-258
classification, 245
exercises, 261-265
formulae for—
cutting speeds, 248-249
length of stroke, 249
number of strokes, 249
Shaping machine—*continued.*
method of drive, 245-246
feed, 246-247
cutting, 247
holding work, 258-260
operations, 261
parts, 245
tools, 251, *252*, 253
groups, 251
types of, 245
clearance angles, 251
types of, 245
uses of, 251, 253
Shearing action, 11, *11*
strength of metals, 130
Shear steel, 14
Shears, bench, *13*, 13
scotch, 12, *12*
Sheet metals, 40
alloyed, 42-43
covered, 40-41
ferrous, 40
gauging, 43
groups, 40
pure, 42
Sherardizing, 172
Shrinkage, 312
protection against, 312
Silky Oak, 334
Silica, 145, 146, 305
paint, 306
precipitate of, 36
Silicon, 142
Silicon-carbide, 320
Single ended spanner, *213*, 213
Silver, 155
characteristics, 155
properties, 155
soldering, 29
solders, 30
uses of, 155
Slag, 136, 137, 140, 147
hammer, 139
notch, 137
Sleekers, moulding, 307, *307*
Sliding bevel, 103, *103*
plan of, 330A
Slotted nuts, *193*, 193
Slotting blades, *95*, 95
Slide rest, *229*, 230
Smoothers, moulders, 307, *307*
Snap gauge, 105

Snips, 11
classification, 14
parts, 14
points in using, 13-14
types, 12, *12*
uses, 12-13, 14
Sodium thiosulphate, 337, 338
Soft soldering, 23
process of, 24
Soldering Bit, 15, *15*, *16*
classification, 16
heating the, 16
parts, 15, 17
tinning the, 18
types, 15, 16
uses, 16, 17
weight of, 15
Soldering, 23
Aluminium, 30
fluxes, 20, 21
hard, 27
pewter, 23, 24
silver, 29
soft, 23
Solders, 24
aluminium, 31
composition, 23, 26, 159
properties, 24, 159
silver, 30
uses of, 23, 24, 159
Spanners, 213
length of, 214
offset of jaws, 214, *214*
types, 213-217, *213-217*
uses of, 213-217
using the, 217
Specific gravity of metals, 128-129
Speeds of gearing, 279
Spelter, 27, 171
Spiegeleisen, 140, 141
Spiral fluted reamer, *180*
Spirit level, 115
Split pins, 193, *193*
securing nut, *193*
Spotted gum, 70, 73
Spot weld, 37, 38
Spraying metals, 172, 173
Spring calipers, *125*, 125
washers, *194*, 194
Square root, 380-381
Stabilizing, 167
Stainless Steel, 30, 40, 151-152
characteristics, 152
composition, 151
groups, 151
melting point, 152
properties, 152
uses, 152
Stakes metalworker's, 48
types, *48*, *49*, 49
Standard hachures, *376*
Standard Screw Threads, 197
Statuary, bronze, 315
Steel alloys, 148
age, 136
annealing, 163
Bessemer process, 140-141
blister, 144
cast, 143
castings, 36, 303
carbon, 150
colouring, 338
crucible, 144
cutting, 150
double shear, 144
electric, 144
high carbon, 144
high speed, 150
mild, 140
moulding, 316
moulds—
dressing for, 306
open hearth process, 141-142
polishing, 337-338
shear, 14, 144
spring, 112, 144
stainless, 30, 40, 144, 151
tool, 11, 112, 143
Stellite, 148, 238, 251
characteristics, 150
composition, 150
uses, 150, 238, 251
Step block, *257*, 258
Stocks and dies, 213
using the, 210
stock, details of, 209
types of, 209, 210, *209*, *210*
lubrication of, 211
dies, details of, 209-210
types of, *209-210*, 209-210
Straight, edge, 102
fluted drill, *178*, 178
uses of, 178

Straight, edge—*continued.*
snips, 11, *12*
Strap bolt, 188, *188*
Stud, or Stud bolt, 189-190, *190*
extractor, *190*, 191
driver or box, 190, *190*
Squares, engineer's, 101, 112
classification, 116
parts, 112, 116
types, 112, 116
uses, 113-115, 116
Square thread, 190, *200*
uses of, 199-200
Square root, 380-381
Sulphur, 34, 145, 286
Sulphuric acid, 170, 171, 336
Surface, gauge, 108, *108*
uses of, 109
using the, 108
plate, 101, 109, *110*
care of, 110
use of, 110
shaping a, *261*, 261-262
Swage, block, *289*, 289
top, 289, *289*
bottom, *289*, 289
Sweating, 25, 26

TABLES—
Allowance, British standard, 220
American standard threads, 383
Brazing alloys, 27
British association threads, 383
British and metrical equivalents, 387-388
British weights and measures, 385-386
Circumferences, areas, squares, etc., of circle, 380-381
Colour of metals, 128
Compression of metals, 132
Conductivity of metals, 131
Copper-Zinc alloys, 27
Cutting angles of chisels, 76
Cutting speeds-drills, 185
lathe, 242
shaper, 250
Decimal equivalents, 377
Ductility of Metals, 130

Tables—*continued.*
Feed Rates—
lathe, 242
shaper, 250
Ferrous metals, 135
Fluxes-soldering, 21
Formulae for fits, 222
Fusibility of metals, 132
Grindstone speeds, 319
Grinding wheels-power, 321
speeds, 321
grades, 321
Hacksaw blades-teeth per inch, 95
Hardness of metals, 131
Heats, forge work, 293, 300
Lubricants-drilling, 186
lathe work, 243
shaper, 250
Malleability of metals, 130
Melting point of metals, 132
Pig Iron (composition), 138
Revolutions per minute
Grindstone, 319
Grinding wheels, 321
Lathe, 242
Rules relative to circle, 378
Soft solders, 23, 159
Specific gravity of metals, 129
Speeds and feeds, 242, 250
Tapping size of holes, 208, 382, 383
Tempering colours and uses, 165
Tensile strength of metals, 129
Threads per inch, Sellers, 199, 383
Whitworth, 199, 382
British Association, 383
Tin-lead alloys, 23, 157, 159
Weight, of metals, 129
substances, 384
Whitworth standard threads 382
Tantalum, 149-150
characteristics, 149-150
properties, 149-150
uses, 150
Taper gauge, *106*, 106-107
Taps, extraction of, 207
humouring, 207
lubrication of, 207

Taps—*continued.*
methods of keeping square, 206, *206*
parts, 203
set of, 203-204, *204*
sharpening, 207
uses of, 203
wrenches, *206*, 206
Tapping, depth of holes, 203
lubricants, 207
procedure, 206-207
size of holes—
formula for, 205
Tempering, 164
method of, 165
Tenacity of metals, 129
Tensile strength of metals, 129
Terne plate, 41, 172
manufacture of, 172
uses of, 41
Thermit welding, 36-37
Threads, standard screw, 197
Through bolts, 187
Tin, 23, 24, 42, 155, 164
annealing, 164
characteristics, 155
properties, 42, 155
uses of, 42, 155
Tinman's dresser, 46, *46*
Tinning, aluminium, 30
the soldering bit, 18
steps in procedure, 19
Tin-lead alloys, 23, 24, 157, 159
characteristics, 159
properties, 159
uses of, 23, 159
Tinplate, gauge of, 41, 43
history of, 170
manufacture of, 170
polishing, 170, 336
uses of, 170
Tipping machine tools, 238-239, 251
method of, 238-239
Titanium, 149
characteristics, 149
properties, 149
uses of, 149
Tolerance, 218, 220
definition of, 220
limits of, 220
methods of indicating, 222-223
Tolerance—*continued.*
nominal dimension, 222
Tongs, crucible, 304
forgework, *287*, 287
Tool clamps, lathe, *230*
Tool holders, 238, *238*
holders, 238, *238*
Tool steel, 11, 143
Cementation process, 143
crucible, 144
electric, 143
properties, 147
uses of, 192
Tools, cutting, 288
knurling, *237*, 237-238
lathe, 234-238, *235*
shaper, 251-253, *252*
Toughness of metals, 133
Tracers, repoussé, 333
Trammels, *120*, 120-121
Transfer calipers, 122-123
Transmission of power, 266
Trenale, 311
Treble best iron, 140
Trowels, moulders, 306, *306*
Try-square, 112-114, *112-113*
testing a, *114*, 114
use of, 113, 117
Truncated cone thread, 200, *200*
Turning, facing, 240
concave and convex, 239-240 *240*
parallel or plain, 239, *240*
screw cutting, 236-237, 241
stepped, 239, *240*
taper, 240, *240*
Tungsten, 149
characteristics, 149
properties, 149
uses, 149
Tuyeres, 137, 141, 284
Twist drills, 175, *177*
details of, 175
sharpening, 177
types of, *176*, 176

UPSETTING, 291, 294-295
Useful tables and data, 378-379

VANADIUM, 144, 147, 149
characteristics, 149
ferro, 146, 150

Vanadium—*continued.*
properties, 149
uses, 149
Varnish, 31
"V" blocks, *109*, 109, 255
uses of, 109, *255*, 259
Venting, 313
Vernier calipers, 126, *126*
Vice, clamps, 63, *63*, 66
classification, 65
engineer's, 59
hand, *62*, 62
height of, 62
instantaneous grip, 61, *61*
leg, 59, *59*
parallel, 60, *61*
shaper, 253
types of, 59, 65

WASHERS, cover, *194*, 195
cutter *180*, 180
lug, 195
proportions of, 188
spring, *194*, 194
uses of, 188
Waste, cotton, 323
Water, cooling, 164
Wedges, levelling, 254, *255*
Weight of metals, 128-129
Weldability of metals, 133
Welding, classification, 32
blowpipes, *33*, 33-34
fluxes, 36
forgework, 291
heat, 291, 292, 295
joints, 34, *35*
methods of, 32

Welding—*continued.*
rods, 34
temperature, 292, 295
types of electric, 37-38
Welds, classification, 296
types of, *296*
Wheelswarf, 143
White metal, 160
composition, 160
properties, 160
uses of, 160
Whitworth thread, 197-198, *198*
uses of, 198
Wing compasses, 119, *119*
Wire drawing, 130
Wiring edges, *55*, 55-56
Woodruff key, 195
Wrought iron, 140
characteristics, 140
manufacture of, 139-140
properties, 140
uses of, 140

ZINCANNEAL, 171-172
Zinc, 20, 155-156, 171
characteristics, 155
chloride, 18, 20, 22, 172
gauge, 44
granulated, 20
oxide, 20
powder, 172
properties, 155
uses of, 155-156
Zirconium, 150
characteristics, 150
properties, 150
uses of, 150